Growth and Yield Response of *Lens culinaris* L. Medic. and *Vigna radiata* L. Wilczek to Nitrogen, Phosphorus and Pyridoxine Application

ABSTRACT

OF THE
THESIS SUBMITTED TO
THE ALIGARH MUSLIM UNIVERSITY, ALIGARH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Doctor of Philosophy

IN

BOTANY

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DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

1988

GROWTH AND YIELD RESPONSE OF *LENS CULINARIS* L. MEDIC. AND *VIGNA RADIATA* L. WILCZEK TO NITROGEN, PHOSPHORUS AND PYRIDOXINE APPLICATION

FAIZAN AHMAD KHAN

Abstract of the thesis, submitted to the Aligarh Muslim University, Aligarh, India for the degree of Doctor of Philosophy in **BOTANY**, 1988

Eight factorial randomised field experiments, four each on lentil (*Lens culinaris* L. Medic.) var. T-36 (Experiments 1-4) and summer moong (*Vigna radiata* L. Wilczek) var. K-851 (Experiments 5-8), were conducted at the University Farm of the Aligarh Muslim University, Aligarh (India) from 1984 to 1986. The aim was to study the effect of basally applied nitrogen and phosphorus and of pre-sowing seed treatment (prior to applying respective *Rhizobium* inoculum uniformly) with aqueous pyridoxine solution, alone and in combination, on growth parameters, net assimilation rate (NAR), nitrate reductase activity (NRA), leaf NPK content, yield parameters and seed protein content of these grain legumes. The data were mostly found significant and are summarised below.

Experiment 1: The trial was conducted during 1984-85. Four doses of nitrogen, i.e., 15, 30, 45 and 60 kg N/ha (B_{N15}, B_{N30}, B_{N45} and B_{N60}), were applied to plots given a uniform basal dose of 45 kg P and 30 kg K/ha. Seeds of lentil were soaked in aqeous pyridoxine solution, i.e., 0% (S_W), 0.2% (S_1), 0.3% (S_2) or 0.4% (S_3) before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 60, 90 and 120d; NAR for 60-90d and 90-120d intervals and yield parameters and seed protein content at harvest. Of these basal nitrogen doses, B_{N30} proved optimum for

most of the parameters. The soaking treatment S_2 promoted almost all parameters studied. The interaction B_{N30} x S_2 proved optimum for most parameters. For example, B_{N30} x S_2 increased seed yield by 71.21% and seed protein content by 12.65% over B_{N15} x S_W.

Experiment 2: The trial was conducted during 1984-85. Four doses of phosphorus, viz., 15, 30, 45 and 60 kg P/ha (B_{P15}, B_{P30}, B_{P45} and B_{P60}), were applied to plots given a uniform basal dose of 45 kg N and 30 kg K/ha. Seeds of lentil were soaked in pyridoxine solution, viz., 0% (S_W), 0.2% (S_1), 0.3% (S_2) or 0.4% (S_3) before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 60, 90 and 120d; NAR for 60-90 and 90-120d intervals and yield parameters and seed protein content at harvest. Of these, B_{P30} and S_2 separately proved optimum for most parameters. While combination B_{P30} x S_1 proved optimum for most parameters. B_{P30} x S_1 enhanced seed yield and seed protein content by 31.05% and 18.27% respectively, compared with B_{P15} x S_W.

Experiment 3: The trial was conducted during 1985-86. Six doses of basal + foliar nitrogen, i.e., $B_{N15}+F_W$, $B_{N30}+F_W$, $B_{N15}+F_{N5}$, $B_{N30}+F_{N5}$, $B_{N15}+F_{N10}$ and $B_{N30}+F_{N10}$ (taking the optimal and sub-optimal basal dose of nitrogen determined in Experiment 1), were applied to plots given a uniform basal dose of 30 kg P and 30 kg K/ha. Seeds of lentil were soaked in 0.2 and 0.3% (S_1 and S_2) aqueous pyridoxine solution before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 120d, NAR for 90-120d interval and yield parameters and seed protein content at harvest. Of these, individual and combined effect of $B_{N15}+F_{N5}$ and S_2 proved optimum for almost all parameters, resulted in a saving of 10 kg N/ha as compared with Experiment 1. The interaction ($B_{N15}+F_{N5}$) x S_2 increased seed yield by 21.04% and seed protein content by 6.35% over ($B_{N15}+F_W$) x S_1.

Experiment 4: The trial was conducted during 1985-86. Six doses of basal and foliar phosphorus, viz., $B_{P20}+F_W$, $B_{P30}+F_W$, $B_{P20}+F_{P1}$, $B_{P30}+F_{P1}$, $B_{P20}+F_{P2}$ and $B_{P30}+F_{P2}$ (taking the optimal and sub-optimal basal phosphorus dose determined in Experiment 2), were applied to plots given a uniform basal dose of 30 kg N and 30 kg K/ha. Seeds of lentil were soaked in 0.2% (S_1) and 0.3% (S_2) pyridoxine solution before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 120d, NAR for 90-120d interval and yield parameters and seed protein content at harvest. Among different levels of phosphorus (basal + foliar) and soaking treatments, $B_{P20}+F_{P2}$ and S_2, alone as well as in combination, proved optimum for all parameters, resulted in a net saving of 8 kg P/ha as compared with the optimum dose determined in Experiment 2. The combination $(B_{P20}+F_{P2}) \times S_2$ resulted in an increase of 24.13% and 16.36% in seed yield and seed protein content respectively over $(B_{P20}+F_W) \times S_1$.

Experiment 5: The experiment was conducted during 1985. Four doses of nitrogen, i.e., no nitrogen (B_{N0}), 5 kg N/ha (B_{N5}), 10 kg N/ha (B_{N10}) and 15 kg N/ha (B_{N15}), were applied to plots given a uniform basally applied 30 kg P and 35 kg K/ha. Seeds of moong were soaked in 0.0% (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3) pyridoxine solution before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 20, 30, 40 and 50d; NAR for 20-30, 30-40d and 40-50d intervals and yield parameters and seed protein content at harvest. Of these, B_{N5} and S_2 proved optimum for almost all parameters. Among different interactions, $B_{N5} \times S_1$ proved optimum for most of the parameters. This interaction resulted in an increase of 31.72% and 7.86% in seed yield and seed protein content respectively over $B_{N0} \times S_W$.

Experiment 6: The effect of basally applied phosphorus, viz., B_{P15}, B_{P30}, B_{P45} and B_{P60} and pre-sowing seed treatments with aqueous pyridoxine solution, i.e., 0.0% (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3) alone and in combination, was studied in the presence of 10 kg N and 35 kg K/ha applied uniformly at the time of sowing, on growth parameters, NRA and leaf NPK content at 20, 30, 40 and 50d; NAR for 20-30d, 30-40d and 40-50d intervals and yield parameters and seed protein content at harvest in 1985. Among these, B_{P30} and S_2 separately proved optimum for all parameters, while B_{P15} x S_2 emerged as the best combination for all parameters. The interaction, B_{P15} x S_2 enhanced the seed yield and seed protein content by 31.06% and 11.75% respectively over B_{P15} x S_W.

Experiment 7: The experiment was conducted during 1986. Five doses of basal + foliar nitrogen, i.e., $B_{N2.5}+F_W$, $B_{N5}+F_W$, $B_{N2.5}+F_{N1.25}$, $B_{N2.5}+F_{N2.5}$ and $B_{N2.5}+F_{N5}$ (taking the optimal and sub-optimal basal nitrogen dose determined in Experiment 5), were applied to plots given a uniform basal dose of 15 kg P and 35 kg K/ha. Seeds of moong were soaked in 0.2% (S_1) and 0.3% (S_2) aqueous pyridoxine solution before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 40 and 50d; NAP for 30-40 and 40-50d intervals, yield parameters and seed protein content at harvest. Of these, $B_{N2.5}+F_{N1.25}$ and S_2 alone and in combination proved optimum for all parameters studied. Although it resulted in a saving of only 1.25 kg/ha of nitrogen, it increased seed yield by 20.27% and seed protein content by 7.12% over ($B_{N2.5}+F_W$) x S_1.

Experiment 8: The trial was conducted during 1986. Six doses of basal + foliar phosphorus, i.e., $B_{P10}+F_W$, $B_{P15}+F_W$, $B_{P10}+F_{P1}$, $B_{P15}+F_{P1}$, $B_{P10}+F_{P2}$ and $B_{P15}+F_{P2}$ (taking the optimal and sub-optimal basal phosphorus dose determined in Experiment 6), were applied to plots given a uniform basal dose of 5 kg N and 35 kg K/ha. Seeds of moong were soaked in 0.2% and 0.3%

(S_1 and S_2) pyridoxine solution before sowing. The individual and combined effects of these treatments were studied on growth parameters, NRA and leaf NPK content at 40 and 50d; NAR for 30-40 and 40-50d intervals, yield parameters and seed protein content at harvest. Treatments, $B_{P10}+F_{P2}$ (equalled by $B_{P15}+F_{P1}$) and S_2 proved best for most parameters separately. Among various combinations, $(B_{P10}+F_{P2}) \times S_2$ excelled all other interactions and proved optimum for all parameters, increasing seed yield and seed protein content by 35.66% 19.33% respectively over $(B_{P10}+F_W) \times S_1$ with a saving of 18 kg P/ha as compared with the Experiment 6.

The information contained in this thesis is new addition to the literature on the growth, development and seed quality of grain legumes in particular and crop plants in general in the following respects:

1. The optimum requirement of nitrogenous and phosphatic fertilisers for lentil and summer moong (Experiment 1,2, 5 and 6) for the agro-climate obtaining at Aligarh (Western Uttar Pradesh) was determined with precision.
2. The concentration of pre-sowing seed treatment with aqueous pyridoxine (vitamin B_6) solution for optimum performance of the two crops was repeatedly confirmed in all trials undertaken (Experiments 1-8).
3. The optimum combinations of nitrogenous or phosphatic fertilisers with soaking treatments were determined for the first time (Experiments 1-8).
4. In conclusion, comparison of all experiments reveals that supplemental foliar spray of nitrogen and phosphorus was effective and economical for both lentil and moong. Whereas, 0.3% aqueous pyridoxine solution as pre-sowing seed treatment has invariably pronounced stimulating effect on yield of both crops. Thus, pyridoxine treatment promotes "soil and

and leaf-applied nutrient use efficiency" in both crops. Therefore, minimum application of nutrients (nitrogen and phosphorus) in combination with 0.3% aqueous solution of pyridoxine treatment of seeds may be exploited economically to augment the yield and seed quality of lentil and summer moong.

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CERTIFICATE

This is to certify that the thesis entitled, "Growth and Yield Response of Lens culinaris L.Medic.and Vigna radiata L.Wilczek to Nitrogen, Phosphorus and Pyridoxine Application", submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Botany, is a faithful record of the bonafide research work carried out at the Aligarh Muslim University, Aligarh, by Mr. Faizan Ahmad Khan under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

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Dedicated to my Grandfather

ACKNOWLEDGEMENTS

I feel indebted to Dr. Samiullah, Reader in Botany, Aligarh Muslim University, Aligarh, for guidance during the present investigation and continued interest in the preparation of the manuscript.

I owe a sense of gratitude to Professor M.M.R.K. Afridi for his advice and constructive criticism and to Prof. Khalid Mahmood, Chairman, Department of Botany, for providing necessary research facilities.

I place on record my sincere thanks to Drs S.H. Afaq, Aqil Ahmad, Arif Inam, M.A. Parvaiz, Firoz Mohammad, Masood Akhtar, M.M.A. Khan, Shamim A. Ansari, Moinuddin and Nafees A. Khan, Ms. Atiya Khatoon Zaidi, Nasreen Fatima and Syeda Shama Muzaffar and Messrs Saood Husain, Mujahid A. Khan, Shahid Umar, Ikramul Haque, Syed Rushdi Mohammad Ata, Aquil Ahmad and Tauheed Khan for their cooperation.

I am particularly grateful to my parents, brothers and sisters, who remained a constant source of inspiration and encouragement. My wife also deserves special mention in this regard. She not only endured long hours of solitude patiently and absolved me of all household duties willingly but also kept my spirits high.

I am also thankful to my friends specially Messrs Faiz A. Khan, Masud Ahmad, Ch. Mashkoor Ahmad, Iqbal Ahmad and Murad A. Usmani for encouragement and moral support.

Lastly, the award of a Junior Research Fellowship by the Aligarh Muslim University, Aligarh and of a Senior Research Fellowship by the Council of Scientific and Industrial Research, New Delhi is gratefully acknowledged.

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CONTENTS

CHAPTER 1

INTRODUCTION

CHAPTER - 1

INTRODUCTION

Early man started agriculture after recognising the nutritive value of different wild plants. Therefore, it is not surprising that, together with cereals, leguminous crops were cultivated in the distant past. Of these, at least "Masha" (Urd, i.e., *Phaseolus radiatus* Roxb.), "Masura" (Lentil, i.e., *Lens culinaris* L. Medic.) and "Mudga" (Moong, i.e., *Vigna radiata* L. Wilczek) are mentioned in early Aryan literature and date back to thousands of years (Achaya, 1985). The early Roman and Greek farmers have also been credited with the knowledge of the beneficial effect of rotating leguminous and non-leguminous crops (Bould, 1963; Burris, 1965).

With the advancement of science and technology, agriculture has emerged as an industry in most of the developed and some of the developing countries, like India. As a rule, the success of an industry depends upon low energy investments, accompanied by high output, agriculture being no exception. Of the total energy invested in the agriculture sector of a developed country, like the U.S.A., about a quarter is used for synthetic fertiliser production. It is estimated that there has been a several-fold increase in the input of nitrogenous fertilisers during the past few decades (Flaig, 1978) and there is indication that this trend will continue. The situation in developing countries is even more critical because of the general awakening among farmers coupled with constraints on fertiliser production. In India, for example, the existing gap between production and consumption of nitrogen has been doubled within the last few decades (Subba Rao, 1979) posing a heavy burden on the economy of the country.

Keeping these facts in view, judicious exploitation of the unique mechanism of dinitrogen fixation by leguminous crops could help in more than one way. It increases soil fertility, provides cheap alternative for costly synthetic nitrogenous fertilisers and checks environmental pollution. It is estimated that about 175 million tonnes of dinitrogen are fixed annually by various organisms (Burns and Hardy, 1975; p.54). The forage legumes contribute approximately 125-300 kg/ha, and edible legumes 50-60 kg/ha/year (Mishutin and Shilnikova, 1971). Moreover, leguminous crops, by virtue of their high grain protein content (20-40%), have unequivocally proved indispensable in tropical and sub-tropical regions of the world, including India in particular where the majority of the population depends mostly upon vegetable proteins. Ironically, the so called " Green Revolution" , which helped in meeting the increasing demand of cereals during the recent past and proved successful in coping with the " population explosion" , eclipsed the need for increased production of grain legumes. Therefore, neither the genetic stock nor the agronomic practices for the cultivation of leguminous crops could be improved. The ignorant farmers continue to grow low yielding cultivars of legumes, often as inter-crops, in unirrigated areas. It results in low production inspite of covering 24 million hectares of arable land-the largest area of the world under leguminous crops (Mehta, 1968). It is, therefore, not surprising to note that total production of grain legumes in the country is only about 12 million tonnes, i.e., 500 kg/ha (Jeswani and Vanschaik, 1968; Mann and Singh, 1975) as against 3,494 kg/ha for example, produced by France (Anonymous, 1984). Lately the situation has prompted national planners to give top priority to the task of improving the genetic make-up of these crops and to workout a set of practices for full exploitation of their potential. To achieve genetic limits of yield performance of a crop, it is essential that all the environmental factors contributing to its growth and development should be optimised. Of these, nutrition is a factor of prime importance. With the application of fertilisers and ameliorative additives, crop yield have been improved considerably. However, greenhouse and field studies have revealed that indiscriminate use of fertilisers may prove uneconomical or even sometimes harmful for plant growth and developments. Moreover, a proper balance in the nutrients present in the growing medium is essential for optimum growth and good returns.

Lentil and moong are two important pulse crops of India. The former is a winter season ("rabi") pulse, generally raised under rainfed conditions. It can be sown from the middle of October to the end of November, this providing extra time for engaging the land under a late "kharif" (rainy season) crop. In addition, it requires minimum plant protection measures. Moong has been established as a full fledged off-season summer crop. It enables the farmers to make best use of their fallow land, which consequently becomes rich in nitrogen. As the crop is generally free from diseases during this season, a good yield may be ensured.

At Aligarh (India), Samiullah and his associates have made significant contribution regarding the cultivation of lentil and summer moong within a short span of time (Akhtar and Samiullah, 1982; Samiullah et al., 1982, 1983, 1985; Akhtar et al., 1983, 1984; Akhtar, 1985). These studies have resulted in the establishment of the optimum fertiliser doses and application schedules for some improved varieties. Recently, a modest attempt has been made to improve the productivity and quality of these grain legumes under culture and field conditions by exogenous application of vitamins, particularly vitamin B_6 (pyridoxine). Stimulation of root growth in barley, summer moong, lentil and urd by administering dilute aqueous solution of pyridoxine to seeds (Afridi et al., 1979; Khan and Ansari, 1984; Samiullah et al., 1985, 1988) indicated that pre-sowing treatment with pyridoxine favoured the uptake of water and nutrients by enhancing the area of the interface between roots and soils. This could have added advantage in conserving the applied phosphorus which is very prone to be fixed in the soil (Russell, 1950)

Considering this, it was decided to undertake eight field experiments - four each on lentil and summer moong - to test the effect of the interaction of nitrogen and phosphorus with vitamin B_6. These crops were selected in view of: (i) diversity of genetic material, (ii) possession of fairly high and easily digestible seed protein and limiting amino acid contents, particularly methionine and tryptophan (Gupta, 1982 pp 297, 301), (iii) minimal requirement of irrigation, in view of drought creating adverse conditions every year in one part of India or the other and (iv) distribution of the investigations fairly through out the year.

The aims and objects of these field trials were to study the effect of :

Various doses of nitrogen/phosphorus and pre-sowing seed treatment with graded aqueous pyridoxine solutions, alone and in combination, on the growth and yield response of lentil and moong.

Basal dressing of several doses of nitrogen/phosphorus, supplemented with foliar spray of nitrogen/phosphorus alone or in combination with two concentrations of aqueous pyridoxine solution on the growth and development of lentil and moong.

CHAPTER 2

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Eversince his appearance on this universe, man must have, due to his natural curiosity, made innumerable observations about everything around him and noted many phenomena taking place in his surroundings. Later, some of these were exploited by him for his own welfare. The commencement of agriculture seems to be one such outcome his experience with plants and their relationship with the environment. He must have observed that seeds of a plant, if falling on moist soil, generally produced a fulfledged crop. This phenomenon encouraged his to cultivate the land. As time passed and the population increased, the only alternative left with him was to increase the agricultural production with limited available resources. Since then, gradually several steps have been taken to increase the productivity and quality of the crop. Considerable success has been achieved in understanding the importance of nutrients, particularly Nitrogen, Phosphorus, Potassium, in increasing the yield and quality of crop.

In recent years, attention has been focussed to develop new vistas to achieve this end. Among them, chemical and physical pre-sowing treatment of seeds of high yielding varieties grown with optimum Nitrogen, Phosphorus, Potassium has shown promising results. At Aligarh, seed treatment of barley, lentil and moong with pyridoxine (vitamin B_6) has proved effective as well economical for the purpose (Ahmad et al.,1981; Ansari, 1986). However, detailed study of the effect of the interaction of vitamin with NPK on the productivity and quality of lentil and moong has not been made so far. As mentioned earlier (p.04), therefore, the present investigation was undertaken keeping in view this fact. A brief survey of the available literature is given in the following pages.

2.1 Mineral nutrition of plants

The soil is the matrix which not only supports the plants but also provides them with water and minerals. It consists of minerals, organic matter, water, air and living organisms. Of these, mineral matter, obtained from the parental rocks, forms the bulk of soil solids and is the main natural source of mineral nutrients for plants. Inorganic ions of the soil, derived mostly from mineral constituents, are termed as mineral nutrients (Noggle and Fritz, 1986). These nutrients are imperative to sustain the maintenance of physical organisation of plants. The activity of living cells also depends on them directly by virtue of their function in various molecules constituting the building blocks, participating in the repair of protoplasm and regulating metabolic processes and indirectly through release of energy (Nason and McElroy, 1963). Therefore, some of these nutrients are absolutely essential for plant growth and development and, if deficient, cause serious injuries to the plant.

2.1.1 Brief history

The history of nutrition of plants dates back to the Greek period when Aristotle (384 B.C. - 322 B.C.) recognised the nutritive function of living being, separating the living from the dead. Cato (234 B.C. - 149 B.C.) was the earliest Roman agriculturist, who emphasised the importance of ploughing and urged the need for careful conservation of manure (Bould, 1963).

Research on plant nutrition is considered to have started in the 17th Century. Glauber in 1656 found that saltpetre, obtained from cattle manure, was effective in plant growth. Later, Home in 1755 pointed out that, in addition to saltpetre, epsom salt and potassium sulphate were required for proper plant growth and development (Bould, 1963). More scientific advancement in the concepts of plant nutrition, however, had to await the advent of the 19th Century. De Saussure (1804) was the first to apply mordern experimental methods to the study of plant nutrition. He analysed the plant ash and found that its composition varied with the nature of the soil and age of the plant. Further, he maintained that nitrogen and other mineral nutrients were essential for plant growth and development.

By the middle of the 19th Century, agricultural scientists, became more and more convinced that growth of crop plants was proportionate to the amount of inorganic nutrients present in the soil. This view was propagated among others by

Liebig in Germany, Boussingault in France and Lawes and Gilbert in England. They emphasised that fertility of the soil could be maintained by the application of inorganic mineral salts to the soil (Russell, 1950).

2.2 Role of NPK in plant metabolism

Among various plant nutrients, nitrogen, phosphorus and potassium are considered to be of prime importance. It has been established that a balanced dose of Nitrogen, Phosphorus and Potassium in the presence of adequate amount of other essential nutrients gives much better results than an unbalanced dose. A brief consideration of each of these prime mineral nutrients is made below :

2.2.1 Nitrogen

Plants contain more atoms of nitrogen than of any other element derived from the soil (Viets, 1965). Nitrogen, being a major structural constituent of the cell, plays an important role in plant metabolism. It constitutes numerous metabolically active compounds, like amino acids, proteins, nucleic acids, porphyrins, flavins, flavonoids and alkaloids (Agarwala and Sharma, 1976). Hence, several morphological and physiological factors, like succulence of fruits, length and breaking strength of the fibres, root growth, fruiting capacity, resistance to lodging, winter hardiness, disease resistance, physiological maturity and yield of many crops have been known to be governed by the nitrogen supply to the crops (Black, 1973).

Recent developments in research on inorganic nitrogen nutrition are related to the various aspects of dinitrogen fixation, nitrate reduction and regulation and the consequences of intensity and sites of nitrate reduction as cation/anion balance or the interaction between plant roots and their substrate. Ammonium nitrogen seems to exert some distinct regulatory functions not only in the induction of flower formation but also for increasing the direction of photosynthetic carbon flow towards the Kreb's cycle. The main effect of both ammonium and nitrate nitrogen on plant growth and development, viz., flowering and senescence, however, seems to be causally related to the direct interactions between nitrogen nutrition and phytohormones. The close correlation between nitrogen supply and the formation of cytokinins in the root and their export to the shoot has been clearly demonstrated in sunflower by Wagner and Michael in 1971 and Salama and Wareing in 1979. Nitrogen supply also affects other phytohormones and abscisic acid (Marschner, 1983).

The deficiency of nitrogen results in stunted growth and decrease yield and quality of fruits, vegetables and grains, when the nitrogen supply is a limiting factor, both the rate and the extent of protein synthesis are depressed and flowering and fruit setting are adversely affected (Agarwala and Sharma, 1976).

2.2.2 Phosphorus

Phosphorus is absorbed by the plants as $H_2PO_4^-$ or HPO_4^{--} anions from the soil. Like nitrogen, phosphorus is also a structural component of various cell constituents and metabolically active compounds. It is also present in sugar phosphates; AMP, ADP, ATP; nucleic acids; nucleoproteins and several coenzymes, e.g., NAD, NADP, etc. (Devlin and Witham, 1986). Being a constituent of ADP, Phosphoglyceraldehyde and ribulose phosphate, phosphorus is involved in the basic reactions of photosynthesis. Being a constituent of the nucleic acids, it controls all the processes of life. It helps in the development of plant roots and hastens maturity and also helps in the ripening of the fruits. Inorganic phosphorus exerts important regulatory functions in energy transfer. Intrestingly, Marschner (1983) pointed out that, in the stroma of chloroplats, a concentration of approximately 10 mM almost completely inhibits starch synthesis. This control seems to be exerted mainly via the allosteric regulation of ADPG pyrophosphorylase by inorganic phosphorus.

Deficiency of phosphorus causes many visible effects, viz., acute leaf angle, lack of tillering, prolonged dormancy of lateral buds, premature leaf fall, decrease in size and number of flower primordia and small fruits or seeds. Besides these, its deficiency results in disturbing nitrogen metabolism which causes the accumulation of soluble organic nitrogenous compounds (free amino acids and amides) and decreases in protein content (Bains and Bhardwaj, 1976). Phosphorus deficiency also results in an increase in the accumulation of free reducing sugar, suggesting an involvement of phosphorus in carbohydrate metabolism (Devlin and Witham, 1986).

2.2.3 Potassium

Potassium is the only monovalent cation essential for all plants. Its essentiality as a plant nutrient was known as early as in the year 1866 by Birner and Bucanus (Reed, 1942). A relationship of potassium to starch formation suggested earlier has been firmly established by recent investigators (Greenberg and Preiss, 1965; Nitsos and Evans, 1968, 1969). Potassium affects several other important functions, like osmoregulation, water transport and the translocation of carbohydrates in plants. According to Rains (1976), potassium is important for protein synthesis. Potassium counteracts the ill effects of excessive nitrogen. It gives strength to the stalk thereby increasing the resistance of plants to lodging. Potassium also acts as a catalytic agent and activator for a large number of enzymes, such as pyruvate kinase, acetic thiokinase, succinyl Co A synthetase (Evans and Sorger, 1966; Rains, 1976). Deficiency of potassium results in a decrease in the total and reducing sugars and proteins Its deficiency causes a marked increase in amide and α-amino acid nitrogen. Potassium deficiency also limits CO_2 diffusion through stomata thus resulting in increase in stomatal resistance. Its deficiency also causes an increase in mesophyll resistance. Potassium also affects the N_2 fixation rate in legumes and growth rates of fruits (Marschner, 1983).

2.3 Basal application of Nitrogen, Phosphorus and Potassium in relation to *Lens culinaris* L. Medic. and *Vigna radiata* L. Wilczek.

The requirement of Nitrogen, Phosphorus and Potassium for different crops has been worked out from time to time in different parts of India (Bains and Bhardwaj, 1976). However, compared to other crops, such work on grain legumes (pulse crops) has not been given due attention. In fact, there are few general references in the literature regarding this aspect of grain legume cultivation. Jain (1975) remarked that they respond to an initial dose of nitrogen under Indian conditions as they require time for the development of root nodules before fixation of atmospheric nitrogen could start. He further indicated that grain legumes give good response to phosphorus application also. Chowdhury (1968) mentioned that adequate amount of potassium, in addition to nitrogen and phosphorus, is required for good yield and superior quality of seeds. Some of the important recent specific Indian studies on *Lens culinaris* L. Medic. and *Vigna radiata* L. Wilczek in relation to Nitrogen, Phosphorus and Potassium application are summarised below:

2.3.1 Lens culinaris L. Medic. (Lentil)

Chowdhury et al. (1972) carried out field trials during 1969-70 and 1970-71 on lentil var. L9-12 in sandy loam soils of poor or medium status of fertility. They applied 0, 25 and 50 kg N/ha alone and 25 kg N/ha in combination with 25, 50 and 75 kg P_2O_5/ha. Nitrogen at 25 kg/ha proved optimum when applied with 50 kg P_2O_5/ha in the soil of low fertility levels (20 kg P_2O_5/ha). They also showed that on rich soils (having more than 30 kg P_2O_5/ha), good yields could be obtained even without any fertilisers.

Sekhon et al. (1978) made detailed studies during 1971-75 in relation to productivity of lentil varieties under various conditions, including nutritional treatments, inoculation and soil status. During 1971-72 and 1972-73, the yield response of three lentil varieties (L9-12, B-18, and T-36) to different strains of Rhizobium was studied. In 1971-72, three strains, viz., L1, L4 and L7 and their mixture were taken. This experiment was conducted in loamy-sand soil (low available nitrogen and medium available phosphorus and potassium). In 1972-73, two experiments were conducted. In the first experiment, they observed the individual effect of three strains of Rhizobium (B5, B7 and L1), while in the second the crop received four treatments, viz., control; inoculation with B7 strain and 25 kg N/ha alone and in combination in sandy-loam soil (low available nitrogen and high phosphorus and potassium). In 1973-74 and

1974-75, they repeated the second experiment of 1972-73 with the same treatments on L9-12 cultivar of lentil. During 1975-76, another experiment was conducted on the same cultivar in loamy-sand soil and sandy-loam soil with eight treatments (control, 20 kg N/ha in one and two equal dressings, 40 kg N/ha in one and two equal dressings; 60 kg N/ha in three equal dressings; inoculation with E1 strain alone and in combination with 20 kg N/ha.

In 1971-72, they noted that L4 strain of Rhizobium proved best for all the varieties, except T-36. Regarding the effect of the mixture of these three, it was observed that cultivars showed different response. It was further inferred that the effect of mixed cultures on varieties T-36 and B-18 was at par with that of L1 strain applied alone but was less than the individual effects of L4 and L7 strains. In 1972-73, in the first experiment, they found that all the Rhizobium strains enhanced the productivity of the cultivars compared with control, strain B7 proving best. The data of the second experiment revealed that inoculation alone increased seed yield by about 82% compared with the control (without inoculum and nitrogen). It was also reported that application of 25 kg N/ha alone or in combination with culture gave similar results to that of inoculation alone. The result of this experiment was confirmed by repeating the study in 1975-76 which revealed that combined effect of inoculum and 20 kg N/ha was more pronounced than their individual effects. When the application of any level of nitrogen alone was compared with that of inoculation alone, it was observed that none of the nitrogen treatments gave more yield than that given by inoculation alone. From these results, they concluded that inoculation of lentil with an efficient strain of Rhizobium might be the cheapest practice for enhancing the yield of the crop.

Slinkard and Henry (1978) conducted a field experiment on lentil to evaluate the effect of six levels of phosphorus (0, 16, 33, 50, 67 and 100 kg P/ha). Phosphorus was applied either with the seeds or side-banded 2 cm below and 2 cm beside. This experiment was carried out at two sites (dry and irrigated land). They noted that percent phosphorus in seeds was increased significantly with the increasing rate of applied phosphorus at both dry and irrigated sites. There was no increase in percent phosphorus at Melfort due to the adequate phosphorus. Further, they observed that phosphorus applied as side bands had no consistent effect on lentil seed yield, while the phosphorus placed with the seeds reduced it, and in general, application of phosphorus had no effect on per cent protein in lentil seeds.

Singh et al. (1979) reported the findings of experiments conducted on lentil var. L9-12 during 1975-76. The response of this crop to various levels of irrigation and fertilisers was observed. They assigned six irrigation treatments (no irrigation, one irrigation at 45 days or 75 days or early pod filling stage, two irrigations at 45 and 75 days or 45 days and early pod filling stage) to main plots and five fertility levels (control, Rhizobium inoculum, 25 kg N/ha + inoculum, 50 kg P_2O_5/ha+ inoculum, 25 kg N+50 kg P_2O_5/ha + inoculum) to sub-plots. The maximum grain yield was obtained when the crop received two irrigations (at 45 days after sowing and at early pod filling stage). They further noted that the effect of all fertility levels, including inoculum were at par. Therefore, they recommended the application of Rhizobium alone for net profit.

Bisen et al. (1980) studied the response of lentil (Lens esculenta) to Rhizobium inoculum and fertiliser application under different moisture regimes during three seasons (1974-77). The experiments were laid according to split-plot design. The four sub-plot treatments were : (1) control (neither inoculum nor fertiliser) (2) inoculum (composite culture of L1, L2 and L3), (3) inoculum + 25 kg N/ha and (4) inoculum + 25 kg N/ha + 50 kg P_2O_5/ha. J.L.S.-1, the variety of lentil used for the year 1974-75 and 1975-76 was J.L.S.-1 and for 1976-77 J.L.S.-2. Regarding the moisture regimes, it was noted that in each year, all irrigation treatments, except irrigation at early pod filling stage, gave significantly higher pod number/plant as well as seed yield compared with control (without irrigation). On comparing various nutrient treatments, a combined application of inoculum, 25 kg N and 50 P_2O_5/ha was noted to enhance pod number as well as seed yield over control (without any treatment) in both varieities.

Malik and Sanoria (1981) studied the effect of three *Rhizobium* and/or two *Azotobacter* strains on yield and uptake of nutrients in lentil (*Lens esculenta*). They noted that inoculation with mixture of *Rhizobium* strain F_1 and *Azotobacter* strain B_4 significantly increase Nitrogen, Phosphorus and Magnesium uptake and seed yield, while inoculum given with *Rhizobium* strain C_7 and *Azotobacter* strain B_5 decreased nutrients uptake and yield compared with inoculation with *Rhizobium* strain C_7 only.

Raghu *et al*. (1981) carried out the trials for three years from 1971-74 and observed the performance of two varieties of lentil (L9-12 and LSW_2) in relation to various regimes of irrigation and nutrient supply. In 1971-72, in a split-plot field experiment, they applied two fertility levels, viz., 40:30:20 and 80:60:40, in the form of N, P_2O_5 and K_2O/ha respectively in sub-plots and 15 irrigations comprising irrigation frequencies and growth stages of the crop in the main plots. In 1972-73, sub-plots received 20:30:20, and 40:60:40 as N, P_2O_5 and K_2O kg/ha respectively, while the main plots had the same irrigation treatments as in 1971-72. The experiment in 1973-74 was conducted according to simple randomised block design. A similar scheme of irrigation treatments was applied with a uniform dose of 40 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. It was noted that the number of grains/pod and grain yield were significantly higher in the higher fertility levels compared to low levels in both the years. When the effect of irrigation treatments was taken into consideration, it was found that the number of grains/pod as well as seed yield increased upto three irrigations (at branching, flowering and grain filling stages).

Saxena (1981) reviewed reports on the mineral nutrients requirement of lentil crop grown at different places. It was found that the crop could produce about 2 tonnes seed/ha when grown with about 100 kg N, 28 kg P_2O_5 and 78 kg K_2O/ha. Studies on nitrogen nutrition showed that more than 85 per cent of the total nitrogen requirement of the crop might be fulfilled by symbiotic nitrogen fixation. Application of farmyard manure at 10 to 15 tonnes/ha was recommended for lentil production in Pakistan. The optimum level of phosphatic fertiliser ranged between 40 and 100 kg P_2O_5/ha, depending upon the availability of the phosphorus and the fixing capacity of the soil. However, a linear increase with increasing levels of phosphorus was noted under low rainfall condition. Potassium application did not show positive response due to its high availability in the soil.

Singh and Marok (1981) conducted pot experiments during 1976-77 and 1977-78 on lentil (<u>Lens esculenta</u>) var.L9-12. The crop was grown in 24 soil types which differed in available phosphorus (low, medium and high). They applied four levels of phosphorus (0, 10, 20 and 30 ppm P_2O_5) as single superphosphate with a constant basal dose of 5 ppm of Nitrogen as calcium ammonium nitrate. It was reported that application of phosphorus significantly increased the two years' average grain and straw yield on all the types of soil depending on the phosphorus status of the soil. For example, the increase in both grain and straw yield was significant upto 30 ppm on low phosphorus soil, upto 20 ppm in medium phosphorus soil and upto 10 ppm on high phosphorus soil. The per cent increase in yields in low phosphorus soil was more compared to control, indicating high response of lentil to phosphorus application in this type of soil.

Verma and Kalra (1981) carried out field trials for two years in 1976-77 and 1977-78 on lentil var. L9-12, during the "rabi" season. The soil was sandy loam and the design of the experiment was split-plot. They evaluated the effect of different levels of irrigation, nitrogen and phosphorus on growth and yield attributes of this crop. They assigned four levels of irrigation viz., no irrigation (control), one irrigation at the age of 60 days, one irrigation at the age of 105 days, two irrigations - one each at 60 and 150 days of crop age; three levels of nitrogen i.e., 0, 20 and 40 kg N/ha and three levels of phosphorus, viz., 30, 60 and 90 kg P_2O_5/ha. The levels of irrigation were assigned to the main-plots and combinations of nitrogen and phosphorus to sub-plots. They noted that an increase in number of irrigation, increased nitrogen and phosphorus uptake, maximum being under two irrigations. Application of 20 kg N and 60 kg P_2O_5/ha significantly enhanced nitrogen and phosphorus contents of grain as compared with 0 kg N and 30 kg P_2O_5/ha. Phosphorus and protein contents of the grain, however, were not influenced by any of the treatments.

Sekhon et al. (1983) carried out field trials during 1972-75 in sandy-loam and during 1975-77 in loamy-sand soil on lentil var. L9-12. The seeds were inoculated with Rhizobium. In 1972-74, the experiment was conducted in sandy-loam soil after paddy harvest, using single superphosphate. The experiment comprised seven treatments, viz., no fertiliser, 25, 50 and 75 kg P_2O_5/ha, as soil dressing at sowing and the same levels applied in two equal applications, half as soil dressing plus half as foliar spray, applied in 3 equal doses, i.e., before flowering, at flower initiation and at pod formation stage. During 1974-75 phosphorus at the rate of 25, 50 and 75 kg P_2O_5 as a soil dressing only was applied because of the fact that in the previous experiments no extra effect of foliar spray was noted. In 1975-77, the experiment was conducted in loamy sand soil, using 5 levels of phosphorus, viz., 0, 20, 40, 60 and 80 kg P_2O_5/ha. In all the experiments, a uniform basal dose of 25 kg N/ha was also applied and seeds were treated with Rhizobium before sowing. They observed that 50 kg P_2O_5/ha in 1972-75 increased grain yield by 23 per cent, pods/plant by

42 per cent and nodulation by 46 per cent in sandy-loam soil. Phosphate at 40 kg/ha in 1975-77 increased seed yield by 40 per cent, pods/plant by 56 per cent and nodulation by 46 per cent in loamy sand soil. It was also found that nodulation was more in the loamy sand soil in comparison with sandy loam soil.

Two field experiments were conducted by Varma and Kalra (1983) on lentil var. L9-12 during 1976-77 and 1977-78 to study the effect of fertilisers and moisture regimes on grain yield. It was reported that application of 20 kg N and 60 kg P_2O_5/ha proved optimum. Regarding the irrigation treatments, it was found that two irrigations (at 60 and 105 days after sowing) gave higher yield over one irrigation at 60 or 105 days and unirrigated control.

Nema <u>et al</u>. (1984) conducted the field trials for three years during the winter seasons of 1974-77. The aim of the experiments was to study the response of lentil var. JLS-1, to irrigation and fertility levels. The experiment was carried out in a split-plot design with four replications. Six irrigation treatments were given in main plots and four fertility levels were applied to sub-plots. The irrigation treatments were L_1 : (control) without irrigation; L_2: single irrigation at pre-flowering stage 45 days after sowing (DAS); L_3: single irrigation at post-flowering stage (75 DAS); L_4: single irrigation during pod filling (85 DAS); L_5: irrigation at both pre- and post-flowering stages (45 + 75 DAS); L_6: irrigation at both pre-flowering and pod filling stages (45 + 85 DAS). The fertility treatments were: F_1: (control); F_2: inoculation with Rhizobium culture; F_3: inoculation + 25 kg N/ha as urea; F_4: inoculation + 25 kg N/ha + 50 kg P_2O_5/ha as single superphosphate. They concluded that irrigation significantly increased seed yield, plant height and 100 seed weight. Among the single irrigation treatments, preflowering irrigation L_2 gave the highest seed yield, delayed irrigation causes marked reduction in seed yield. However, the 100 seed weight was significantly higher when the irrigation was given at pod-filling stage. Among the fertility levels, 25 kg N + 50 kg P_2O_5 + inoculation gave significantly higher seed yield than all other levels with an additional economic gain of Rs. 333/ha over the control. Moreover, it was found that two irrigations, one at pre-flowering and one at post-flowering stage, along with higher fertility levels, showed an increase in seed yield of 134.1% over the control (no irrigation or fertilizer).

Samiullah et al. (1984) carried out an experiment on (Lens culinaris L. Medic. var.T-36), to study the effect of three levels each of basal nitrogen (N) and phosphorus (P) at the rate of 15, 30 and 45 kg/ha in all possible combinations, with and without inoculum on yield parameters, namely, pod number/plant, pod length, seed no./pod, 1,000 seed weight and seed yield at harvest. The soil texture was sandy loam;

pH, 8.5 and available nitrogen, phosphorus and potassium, 171.2, 26 and 613 kg/ha respectively. A uniform basal dose of 30 kg/ha potassium was applied to each plots. Urea, monocalcium superphosphate and muriate of potash were used as a source of nitrogen, phosphorus and potassium respectively. Seeding rate was 50 kg/ha. The trial was based on split-plot design and consisted of two main plots comprising nine 5 sq.m sub-plots. In one main plot, the seeds were treated with Rhizobium inoculum, while the other was without culture. Thus in all, there were eighteen sub-plots, each replicated thrice.

The effect of sub-plot and main plot treatments, were found significant for most of the yield characteristics. Among sub-plot treatments, $N_{45}P_{30}$ proved best for yield parameters. It increased pod number/plant, pod-length, seed number/pod, 1,000 seed weight and seed yield by 46.7%, 52.6%, 83.0%, 12.0% and 38.9% respectively compared with the lowest basal dose ($N_{15}P_{15}$). On comparing the values of main plot means, it was noted that the response of the crop was more pronounced in the presence of Rhizobium inoculum. The culture increased pod number/plant by 12.5%, pod-length by 7.7%, 1,000 seeds by 1.5% and seed yield by 12.2 %. The difference of main plot means at the same level of sub-plots showed that most of the yield attributes were higher with sub-plot treatments x culture than their counterpart, for both main plots, $N_{45}P_{30}$ proving optimum. On comparing sub-plot means at the same level of main plot, it was noted that most of the sub-plot treatments gave higher values for all the yield attributing parameters than their respective control at each main plot levels. $N_{45}P_{30}$ with culture gave the best results, the per cent increases for yield attributes were 49.8, 50.6, 87.5 and 15.7 for pod number/ plant, pod length, seed number/pod and 1,000 seed weight respectively over the control, i.e., lowest basal dose (N_{15} x P_{15}) with culture. These parameters were further found to be positively correlated with seed yield having correlation coefficient (r) = + 0.933, + 0.856, + 0.874 and + 0.840 respectively.

Akhtar et al. (1987) reported the findings of a field experiment conducted on lentil (Lens culinaris L. Medic.) cv. T-36 according to split plot design. The soil was sandy loam, pH 8.5 and available nitrogen, phosphorus and potassium: 171.2, 26.0 and 913.0 kg/ha. Three doses, each of basal nitrogen and phosphorus (15, 30 and 45 kg N or P/ha) in nine possible combinations, namely, $N_{15}P_{15}$, $N_{15}P_{30}$, $N_{15}P_{45}$, $N_{30}P_{15}$, $N_{30}P_{30}$, $N_{30}P_{45}$, $N_{45}P_{15}$, $N_{45}P_{30}$ and $N_{45}P_{45}$ were applied as sub-plot treatments. The two main plots received Rhizobium inoculated and uninoculated seeds at the rate of 20 kg/ha. A uniform basal dose of potassium was applied at the rate of 30 kg K/ha. The size of each plot was 5 sq.m. Thus, in all there were eighteen treatments each replicated thrice. Urea, monocalcium superphosphate and muriate of potash were used as sources of nitrogen, phosphorus and potassium respectively. In main plots it was observed that inoculum increased the leaf-

NPK and seed protein contents compared with the uninoculated control. On comparing the values of sub-plot means, it was found that treatment $N_{45}P_{30}$ was optimum for leaf-NPK contents at all the three growth stages and seed protein content at harvest. However, more pronounced results were obtained in the interaction $N_{45}P_{30}$ x Rhizobium. The leaf-NPK contents at the three growth stages (60, 90 and 120 days) showed a strong and consistent correlation with seed yield and seed protein content. On the basis of this study it may be suggested that leaf-NPK content at early growth stages could be reliably employed to correct deficiencies of nitrogen, phosphorus and potassium so as to ensure high productivity and good quality of the lentil.

2.3.2 Vigna radiata L. Wilczek (Moong)

Sreenivas et al. (1968) conducted a field trial on moong (Phaseolus aureus) var. China-781, during four years from 1960-61 to 1965-66. Three levels of P_2O_5 and farm yard manure (F.Y.M.) were applied in six possible combinations, viz., No P_2O_5 + No F.Y.M., 22.42 kg P_2O_5/ha + No F.Y.M., 44.84 kg P_2O_5/ha + No F.Y.M., No P_2O_5 + 5,600 kg F.Y.M./ha, 22.42 kg P_2O_5/ha + 5,600 kg F.Y.M./ha and 44.84 kg P_2O_5/ha + 5,600 F.Y.M./ha. The data revealed that application of P_2O_5 to moong crop significantly increased the yield in three years out of four. It was also noted that phosphorus applied alone at the rate of 44.84 kg P_2O_5/ha gave significant increase of 0.71 q/ha seed over control. On the other hand, F.Y.M. had no significant effect on seed yield. Therefore, 44.84 kg P_2O_5/ha was recommended for this veriety of moong.

Lochaiyukul et al. (1970) conducted a field trial to find out the effect of nitrogen and plant population on morphology, development and yield of uninoculated mungbean (Phaseolus aureus). They applied 0, 50 or 100 kg N/ha and maintained a population of 1,04,000, 2,08,000, 3,12,000 or 4,16,000 plants/ha at four sites on a hill. They observed that application of nitrogen was important for early growth of the crop but did not prove useful for later stages of development, perhaps due to the effective N_2 fixing Rhizobium present in the soil. For plant population, it was observed that higher population increased leaf area index, total dry matter, all growth components at all stages of growth and seed yield at harvest.

Arora and Luthra (1971) conducted a pot experiment with silica sand to study the effect of nitrogen, phosphorus and potassium alone and in combination on the nitrogen metabolism of leaves of Phaseolus aureus Linn. var. Jalgaon 781. They used two doses of nitrogen (15 and 30 ppm), three of phosphorus (20, 40 and 60 ppm) and four of sulphur (30, 60, 90 and 120 ppm). A control ($N_0P_0S_0$) was also included in the scheme. Leaf samples were collected at 15, 30, 50 and 75 days after germination. They noted that all the nitrogen fractions in the leaves decreased with advancement of the age of the crop except the amide and ammoniacal nitrogen which increased upto 30 days and then started to decrease. Regarding the effect of nutrients, it was noted that the highest dose of N (30 ppm) in combination with 20 ppm P and 120 ppm S proved optimum for amide nitrogen and nitrate nitrogen contents in the leaves at 15 and 30 day stages. P at the rate of 60 ppm in combination with 120 ppm S and 15 ppm N decreased the contents of amino nitrogen, amide nitrogen, ammoniacal nitrogen and nitrate nitrogen compared with other combinations of N, P and S at all growth stages. The effect of S, in combination (90 ppm S, 30 ppm N and 60 ppm P) proved optimum for total nitrogen, protein nitrogen and total soluble nitrogen at 15 and 30 days but this combination decreased amino, amide, ammoniacal and nitrate nitrogen contents in comparison with other combinations.

Choudhry and Bhatia (1971) carried out a field trial on moong var. Pusa Baisakhi, on sandy loam soil of low fertility. They observed the effect of fertilisers (125 kg ammonium sulphate alone and in combination with 200 and 400 kg superphosphate/ha on the productivity of this crop . These fertiliser treatments were given by three different methods (broadcast, drilled with seeds and placed 5-6 cm below the seeds). They noted that application of 125 kg ammonium sulphate applied without super phosphate below the seeds gave best results compared with the same amount of fertiliser applied by the other two methods. It increased the average yield from 4.7 q/ha in the control to 8.1 q/ha, about 22.7 per cent increase over broadcast application and 72.3% over the no fertiliser control. The application of 125 kg ammonium sulphate in combination with 200 kg superphosphate further increased the yield to 10.6 q/ha when placed below the seeds. A combination of 125 kg ammonium sulphate and 400 kg superphosphate/ha, placed below the seeds, had a more spectacular effect. It enhanced the yield from 4.7 q in the control to 12.7 q/ha which was 35.1 per cent higher than in broadcast.

Singh and Choubey (1971) carried out a field experiment on moong at Jabalpur to test the efficiency of three Rhizobium strains (strain A, B and C). The efficiency was compared with the application of various levels of nitrogen (0, 20, 40 and 80 kg N/ha), applied in the form of ammonium sulphate. It was noted that all the three strains significantly increased the yield over the no inoculation or no nitrogen application. Among three strains of Rhizobium used, strain A proved best for the productivity of moong. When efficacy of all three strains was compared with different levels of nitrogen, it was found that all three strains were more efficient than the application of 20 kg N/ha. However, strain A proved as good as 40 kg N/ha. It was concluded that proper inoculation with an efficient strain of Rhizobium may be considered a good technique for enhancing the yield of moong.

Arora and Luthra (1972) studied the effect of N, P and S on the protein content of seeds of (Phaseolus aurens Linn.) var. Jalgaon 781. They found that protein content was increased by the application of sulphur, phosphorus and nitrogen from 19.69% to 24.31%. Moreover, the combined effect of these nutrients was more pronounced on protein content in comparison with their single application. The sulphur containing amino acids (methionine, cysteine and cystine) were increased with increasing doses of sulphur upto 90 ppm. Phosphorus, at lower levels, slightly increased the contents of these amino acids when applied alone; but in combination with higher levels of sulphur and nitrogen, the contents of these amino acids were decreased. Higher dose of nitrogen (30 ppm) decreased the contents of methionine, cysteine and cystine. The sulphur containing amino acids showed significant positive correlation with protein content of the seed.

Moula and Krishnamoorthy (1972) conducted a pot culture experiment to study the performance of moong (HB-45) grown with recommended doses of the macro-nutrients (N-10, P_2O_5 -50 and K_2O-30 kg/ha) in relation to growth and uptake of N, P, K, Ca, Mg and Mn. The growth, as measured by dry matter production, was almost curvilinear. Absorption of all the plant nutrient elements followed closely the dry matter pattern. There was only one peak rate of dry matter production and absorption of all nutrients studied which coincided with intense vegetative growth and flower and pod initiation phase occuring between 30th and 40th day. Nitrogen and phosphorus preferentially accumulated in pod, while the other elements were found in the vegetative portion. The crop produced 1,700 kg/ha total dry matter, of which 640 kg comprised the grain and absorbed 30, 11 and 18 kg/ha, N, P_2O_5 and K_2O respectively in the ratio of 1.0:0.3:0.6. The study showed that the application of N, P_2O_5 and K_2O at 10, 50 and 30 kg/ha, along with a basal dose of 7,500 kg of well rotted FYM, might be expected to meet the requirement of both secondary and micronutrient elements of the crop.

An experiment was conducted by Pande (1972) on Pusa Baisakhi moong during "rabi" season of 1970. He applied three levels of nitrogen (0, 30 and 60 kg N/ha) and four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) alone and in combination to study their effect on growth and yield characteristics. The increasing levels of nitrogen increased plant height, average weight of seeds/pod, grain yield and husk yield/ha. Among nitrogen levels, the highest seed yield of grain (8.61 q/ha) and husk (74.4 q/ha) was obtained with 60 kg N/ha and among phosphorus levels, the maximum grain (8.39 q/ha) and husk (68.1 q/ha) was produced in 90 kg P/ha. The effect of nitrogen as well as of phosphorus was non-significant on the other parameters. The control gave minimum values. The response of the crop was more spectacular with combined application of 60 kg N and 90 kg P/ha and this treatment gave 10.35 q/ha grain yield, while the lowest yield of 3.98 q/ha was obtained in the N_0P_0 control. However, the application of 30 kg each of N and P_2O_5 proved economical.

Sahu and Behera (1972) studied the response of green gram (Phaseolus aureus) to inoculation and application of phosphorus (22 kg P/ha) alone and in combination and compared it with control, in a sandy loam soil during the year 1966-67. They found that the effect of the combined treatment (inoculation + phosphorus) was more pronounced than that of inoculation or phosphorus alone. They also noted that nitrogen content in shoot and root increased gradually till flowering and declined thereafter. This trend might be due to the translocation of nitrogen to grain for protein synthesis. Number of nodules/plant increased till the formation of pods and then decreased due to their degeneration. Application of phosphorus in combination with inoculum increased the protein content of grain by 1.5% compared to the control.

Venugopal and Morachan (1974a) conducted a field trial on two varieties of moong (Rajendran and Pusa Baisakhi) during "Kharif" 1972 according to a split plot design. Four levels each of nitrogen (0, 10, 20 and 30 kg N/ha) and phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) were combined factorially and assigned to main plots. The sub-plots received the two varieties of moong. Plant samples were collected at 30 (pre-bloom), 45 (bloom) and 60 days (maturity) to study the uptake of NPK, Leaf nutrients were noted to be maximum at pre-bloom stage (30 days). Variety Rajendaran showed more nitrogen uptake than Pusa Baisakhi. Regarding the effect of fertilisers on NPK uptake, phosphorus application increased nitrogen uptake when low levels of nitrogen were applied. It was also noted that in the absence of nitrogen (N_0), 40 and 60 kg P_2O_5/ha did not bring about a corresponding increase in phosphorus content. Combined application of 30 kg N and 60 kg P_2O_5/ha resulted in reduced K content. Regarding dry matter production, it was observed that variety Rajendaran produced more dry matter than Pusa Baisakhi. Application of 30 kg nitrogen and 40 kg P_2O_5/ha alone proved optimum for this parameter. Considering pod number/plant and 1,000 seed weight, it was found that Pusa Baisakhi moong produced more pods; however, seeds were heavier in Rajendaran. Application of 20 kg P_2O_5/ha and 30 kg N/ha separately proved optimum for pod number and 1,000 seed weight respectively. With regard to seed yield, variety Pusa Baisakhi out-yielded Rajendaran and gave optimum yield with the application of 20 kg P_2O_5/ha alone.

Venugopal and Morachan (1974b) conducted field trials in two seasons, viz., "Kharif" and "rabi", under irrigated conditions on the same varieties of moong with the same nutrient treatments as in their previously described experiment (1974a). Comparing the growth parameters, it was noted that variety Rajendaran grew taller having larger leaf area index and produced one and a half time more dry matter than

Pusa Baisakhi. The seasonal variations seemed to play a prominent role in determinig the performance of these varieties as the dry matter production was almost double in "kharif" than in "rabi". Consequently, seed yield in winter was found to be reduced to one third. According to these workers, the decrease in dry matter production and seed yield was perhaps due to low temperature and low humidity. On the basis of these observations, it was suggested that "kharif" season was good for the cultivation of moong. When the seed yield of these varieties was compared, it was observed that mean seed yield of Pusa Baisakhi was almost double that of Rajendaran. It was also found that nitrogen application had no significant effect on seed yield, while phosphorus, at the rate of 20 kg P_2O_5/ha, proved optimum and economical and gave 83 kg/ha more seed yield than the control.

Kaul and Sekhon (1975) studied the effect of various levels of phosphorus and row spacing on mungbean (*Vigna radiata* L.) var. MLI during the "kharif" seasons of 1972 and 1973 in a split plot field experiment. In 1972, four levels of phosphorus, viz., 0, 40, 80 and 120 kg P_2O_5/ha and three row spacings (30, 45 and 60 cm) were included in the scheme while in 1973, five levels of phosphorus, viz., 0, 20, 40, 60 and 80 kg P_2O_5/ha with two row spacings (30 and 45 cm) were tried. They assigned phosphorus levels to main plots and row spacings to the sub-plots. In addition, nitrogen as calcium ammonium nitrate at the rate of 15 kg N/ha was also applied to all the plots in both the years. During 1972, no response to phosphorus application was observed due to initial high phosphorus status of the soil (19 kg P/ha). In 1973, dry matter production, pod number/plant and grain yield were increased upto 80 kg P_2O_5/ha, while increase in plant height and seed number/pod was noted upto 60 kg P_2O_5. However, the values given by 60 and 80 kg P_2O_5/ha were at par with those for 40 kg P_2O_5/ha, proving 40 kg P_2O_5/ha optimum. In this later trial, the observed response to phosphorus application might be due to low initial phosphorus status of the soil (10.2 kg P/ha).

A field experiment on two varieties of moong (J-781 and H-45) was conducted by Singh et al. (1975a) during the " kharif" seasons of 1970 and 1971. The treatments comprised four basal levels of phosphorus (0, 25, 50 and 75 kg P_2O_5/ha) and two of nitrogen (0 and 25 kg N/ha). These nutrients were applied singly as well as in various combinations. Single superphosphate and ammonium nitrate were used as the source of phosphorus and nitrogen respectively. It was noted that H-45 gave superior yield compared with J-781 in both 1970 and 1971. Variety H-45 also had higher protein content than J-781. Application of 25 kg N/ha increased the seed yield by 20.44 and 15.13% over control (no nitrogen) in 1970 and 1971 respectively. The application of nitrogen had no marked effect on protein content of the grain. Regarding the effect of phosphorus, it was noted that application of 25, 50 and 75 kg P_2O_5/ha increased the mean grain yield by about 42, 68 and 71 per cent respectively over the no phosphorus control. The two higher doses of phosphorus gave higher protein percentage in grain over 25 kg P_2O_5/ha and the control. The combination of nitrogen and phosphorus (25 kg N + 75 kg P_2O_5/ha) gave maximum average yield. However, the value was at a par with that given by 25 kg N + 50 kg P_2O_5/ha.

Singh et al. (1975b) conducted a field trial on moong (Phaseolus aureus Roxb.) during the summer season of 1971 and 1972. They applied four levels of basal nitrogen (0, 10, 20 and 30 kg N/ha) and phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) to study their effect on pod number/plant, grain number/pod, 1,000 grain weight and grain yield. Increasing levels of nitrogen upto 20 kg N/ha enhanced all the yield attributes except 1,000 grain weight. This dose resulted in highest grain yield 17.98 q/ha, while control (no nitrogen) gave lowest yield (15.48 q/ha). Application of phosphorus upto 60 kg P_2O_5/ha increased all yield parameters including seed yield that was 7.81 q/ha, while control (no phosphorus) gave 5.15 q/ha.

Panwar et al. (1976) reported the findings of a field experiment conducted on moong (Phaseolus aureus L.) during the "kharif" season of 1971 and 1972. The treatments comprised three levels each of basal nitrogen (0, 15 and 30 kg N/ha) and phosphorus (0, 30 and 60 kg P_2O_5/ha) in 1971; but in 1972 one more level of phosphorus (90 kg P_2O_5/ha) was included in the trial. The effect of nitrogen was non-significant during both the years, while phosphorus application showed a significant gradual increase in seed yield upto 60 kg P_2O_5/ha. A reduction in yield as a result of the application of the highest dose (90 kg P_2O_5/ha) was found in comparison with 60 kg P_2O_5/ha. From this experiment, it was concluded that 51 kg P_2O_5/ha was optimum as well as economical.

A green house pot culture experiment on moong (*Phaseolus aureus* L.) var. G-65 was conducted by Aulakh and Pasricha (1977) in a sandy loam soil low in available sulphur and phosphorus. The treatments were in factorial combination of five levels each of basal sulphur and phosphorus (0, 5, 10, 20 and 40 ppm P or S) applied as $CaSO_4.2H_2O$ and $Ca(H_2PO_4)_2.H_2O$ respectively. In addition, a uniform dose of 25 ppm N as urea, 50 ppm K as KCl and 10 ppm of Zn as $ZnCl_2$ was also given. They observed that sulphur application reduced the phosphorus content both in straw and grain, while it was increased by phosphorus application. On the other hand, application of sulphur increased the S content in straw only, while phosphorus level did not affect the S content in straw. However, in grain, S content was decreased with phosphorus treatments. Phosphorus at the rate of 5 or 20 ppm gave significantly lower values of S content in comparison with control. Regarding dry matter production, it was noted that higher levels of phosphorus (20 and 40 ppm) increase grain and straw yield markedly, while sulphur application showed inhibitory effect particularly on grain yield. Protein content in grain was increased by the application of sulphur. On the other hand, phosphorus application decreased the protein.

From these data, it was concluded that interaction effect (PxS) significantly decreased the nutrient uptake, grain yield and protein content.

Two experiments were laid out under irrigated conditions by Ramakrishnan et al. (1977) during " kharif" season of 1974 and 1975 to study the effect of various combinations of nitrogen and phosphorus on the yield of moong var. CO-2. In Experiment 1, they applied nitrogen at the rate of 12.5, 25.0, 37.5, 56.0 and 62.5 kg N/ha in combination with 50 kg P_2O_5/ha while in Experiment 2, they applied nine combinations of nitrogen and phosphorus (25:50, 25:100, 25:200, 50:50, 50:100, 50:200, 100:50, 100:100 and 100:200 kg N:P_2O_5/ha). The sources of nitrogen and phosphorus were ammonium sulphate and superphosphate respectively. In both experiments the treatment consisting of 50 kg each of N and P_2O_5/ha proved economical for grain yield (11.57 q/ha in 1974 and 14.23 q/ha in 1975). The pooled analysis of both years' data revealed that the combinations 50:50 and 62.5:50 were at par, giving grain yield of 11.28 q/ha and 11.38 q/ha respectively in 1974 and 1975.

Singh (1977) performed field trials for three "kharif" seasons from 1968 to 1970 on a loamy sand soil on moong (*Vigna radiata* Wilczek) var. RS-4 and observed the effect of four fertility levels, viz., no nutrient, 20 and 30 kg P_2O_5/ha alone and in combination with or without inoculum. In 1968, it was found that inoculum alone increased the yield of moong crop upto 51% in comparison with the no inoculum control. However, the yields given by the application of either 20 kg N or 30 kg, P_2O_5 or 20 kg N + 30 kg P_2O_5 with or without inoculum did not show significant differences. During 1970, the trend of results on yield was almost the same as noted in 1968. Phosphorus alone failed to increase yield while nitrogen increased it by a 9%. He also observed that the number of pods/ plant and pod length were not influenced by any of the treatments. However, inoculation increased the size of root nodules with or without fertiliser treatment.

A field experiment under rainfed condition was conducted by Gowda and Gowda (1978) on red sandy loam soil having medium fertility during " Kharif" season of 1974 to study the response of moong to nitrogen, phosphorus and potassium application. These nutrients were supplied basally at the rate of 30 kg N, 60 kg P and 20 kg K/ha individually and in combination. Unfertilised control ($N_0P_0K_0$) was also included in the trial. Ammonium sulphate, single superphosphate and muriate of potash were used as the source of nitrogen, phosphorus and potassium respectively. They observed all yield attributes, including pod yield and grain yield, but response to potassium was non-significant. Among these three nutrients, the effect of phosphorus was more pronounced. The combined dose of NPK fertilisers further boosted the pod as well as grain yield. It was concluded that moong could be grown profitably with the application of only phosphorus. However, they also noted that for ideal yields, application of nitrogen and potassium should not be ignored.

Kushwaha and Srivastava (1978) conducted a field experiment on moong (Phaseolus aureus Roxb.) var. T-44 in " Kharif" season of 1976. They applied two levels of nitrogen (0 and 15 kg N/ha), three of phosphorus (0, 40 and 80 kg P_2O_5/ha) and two of inoculum (no inoculation and inoculation) to study the effect of test weight, protein, methionine and tryptophan contents of grain. It was noted that application of inoculum and phosphorus alone increased most of the parameters, while their interaction effect was non-significant. Regarding test weight and protein content, it was noted that application of inoculum, 15 kg N and 80 kg P_2O_5/ha individually increased these parameters over their respective controls. Similarly, application of 15 kg N and 80 kg P_2O_5/ha alone increased methionine content but the effect of inoculum was non-significant. When the value of tryptophan content was taken into consideration, it was found that there was no effect of nitrogen alone, while application of inoculum and phosphorus individually decreased its content compared with their respective controls.

Panwar et al. (1978) observed the effect of four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) in the form of superphosphate on five varieties of moong (T-44, K-141, K-851, Sheela and S-8). The field trial was conducted according to the split plot design, assigning main plots to varieties and sub-plots to phosphorus levels. A uniform basal dose of 15 kg N/ha was also applied as urea to the soil. Among different levels of phosphorus, 60 kg P_2O_5/ha gave maximum yield and 1,000 grain weight of all varieties. Regarding varietal differences, it was noted that K-851 out-yielded all other varieties. It followed by S-8, T-44, Sheela and K-141 in that order with regard to seed yield. Interaction effect (variety x treatment) was non-significant. The economical dose was concluded to be 48.2 kg P_2O_5/ha.

Nair and Aiyer (1979) performed a field trial on a short duration moong variety Co-1 to study the effect of different levels and forms of phosphate on seed yield and removal of nitrogen and phosphorus by the crop. The treatments included a control, lime (CaO) at 500 kg/ha and three levels of phosphorus (15, 30 and 45 kg P_2O_5/ha). Phosphorus was applied from three sources, viz., Mussourie rock phosphate, super-phosphate and factomphos (16:20). The dose of CaO included with phosphorus treatments was maintained at the rate of 500 kg/ha, keeping the nature of phosphorus in view, there was a reduction in amount of CaO when it was given with Mussourie rock phosphate. The fertility of the soil with regard to nitrogen and potassium was maintained at the rate of 20 kg N and 10 kg K_2O/ha. They concluded that the response of the crop in relation to yield was limited upto 15 kg P_2O_5/ha only, and there was no significant response to the different forms of phosphorus. Taking nitrogen and phosphorus contents of grain and straw into consideration, it was observed that both were increased with increasing levels of phosphorus. However, different forms of phosphorus again did not show any effect on these two important yield parameters.

In a split plot block design, Vasimalai and Subramaniam (1980) studied the effect of five levels of phosphorus (0, 25, 50, 75 and 100 kg P/ha) and four irrigation regimes (0.4, 0.6, 0.8 and 1.0 Iw/CPE ratios) on various yield parameters of moong var. Pusa Baisakhi. They assigned fertility levels to sub-plots and moisture regimes to main plots. It was found that the effect of phosphorus levels and moisture regimes had significant effect on plant weight, branching, leaf area index, number of pods/plant, 1,000 seed weight and seed yield. Application of phosphorus at the rate of 50 kg P/ha and IW/CPE ratio of 0.8 proved optimum for seed yield presumably due to the maximum increase in pods/plant in comparison with control. The combination (P_{50} x 0.8 Iw/CPE) further enhanced the productivity of the crop over the control (P_0 x 0.4 IW/CPE).

Khamparia *et al.* (1981) carried out a field trial on three summer moong varieties during summer season of 1979 under irrigated conditions. They applied four levels of fertilisers (control, 10 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha; 20 kg N + 40 kg P_2O_5 + 20 kg P_2O_5/ha and 40 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha) and two levels of inoculum (no inoculum and *Rhizobium* inoculum) in main plots and the three moong genotypes (Pusa Baisakhi, Jawahar-1 and Kopergon) in sub-plots. They reported that all fertility levels significantly increased pod number/plant, pod length, seed number/pod, test weight, seed yield and seed protein content compared with control. The dose 40 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha proved most effective. This treatment increased seed yield by 38% over unfertilised control. Application of inoculum also increased all parameters significantly, except test weight compared with uninoculated control. Among varieties, it was found that Pusa Baisakhi out-yielded the two others and gave maximum yield with 40 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha.

A split-plot fertiliser trial was carried out by Panwar and Singh (1981) on moong var. K-851 during summer season of 1978. They applied four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) in sub-plots and two levels of first irrigation at 18 and 28 days and three levels of subsequent irrigation at 10, 15 and 20 days in main plots. A uniform basal dose of nitrogen at the rate of 15 kg N/ha was also applied to the soil. Nitrogen and phosphorus were applied in the form of urea and monocalcium superphosphate respectively. Regarding the fertility treatments, it was found that application of 30 kg P_2O_5/ha proved optimum for active nodule number, grain number, 1,000 grain weight, grain yield and grain protein yield but number of pods/plant and grain protein content were maximum in 60 kg P_2O_5/ha. They concluded that 40 kg P_2O_5/ha was economical with regard to yield. Taking the effect of irrigation treatment on various parameters into consideration, it was noted that first irrigation at 28 days after sowing significantly increased number of grain/pod, 1,000 grain weight, grain yield and grain protein yield while subsequent irrigation at an interval of 10 days significantly increased seeds/plant, grain number, grain yield and grain protein yield.

A field experiment was conducted by Goverdhan and Manohar (1982) during the monsoon season of 1978 to study the effect of phosphorus levels, H_2SO_4 and micronutrient spray on uptake of nutrient and quality of green gram. They applied three levels of basal phosphorus, viz., 0, 30, 60 kg P_2O_5/ha and five levels of foliar spray i.e., control; 0.1% H_2SO_4; 0.5% $FeSO_4$; 0.5% $MnSO_4$, and 0.5% $ZnSO_4$ respectively. A uniform basal dose of 5.5 tons/ha FYM and 15 kg N/ha as urea were also applied before sowing. Phosphorus was applied as single superphosphate. Thus, in all there were 15 treatments. The spraying was done at 30 and 45 days of sowing. They noted that the application of 60 kg P_2O_5 followed by 30 kg P_2O_5/ha significantly increased the nitrogen, phosphorus and protein contents in grain and straw respectively. Foliar application of H_2SO_4 increased the uptake of P_2O_5 significantly over control, contrary to this, it decreased the nitrogen uptake significantly incomparison to control. Further it has been noted that the uptake of nitrogen and phosphorus by the green gram significantly increased due to application of $ZnSO_4$, $FeSO_4$ and $MnSO_4$. The maximum uptake, however, was recorded with $ZnSO_4$, which gave 56.8% increase in the uptake of nitrogen and 21.1% more protein in straw and grain respectively over the control. The interaction effect of P_2O_5 and micro-nutrients was found significant on protein content of green gram. Maximum protein content in the grain was recorded by the combination 30 kg P_2O_5 x 0.5% $FeSO_4$. Maximum phosphorus content in the grain was recorded by 0 kg P_2O_5 x 0.1% H_2SO_4, followed by 30 kg P_2O_5 x 0.5% $ZnSO_4$.

Samiullah et al. (1982) performed a factorial randomised field trial on the effect of basal nitrogen and phosphorus and of their interaction on yield characteristics of summer moong (Vigna radiata var. T-44). They applied four levels of nitrogen (0, 10, 20 and 30 kg/ha) and four levels of phosphorus (0, 30, 45 and 60 kg P_2O_5/ha) as urea and superphosphate respectively. They studied five yield parameters, namely, pod number and pod length, seed number, 1,000 seed weight and seed yield. At harvest, it was found that moong showed a significant response to both nitrogen and phosphorus application regarding all yield parameters. It was noted that 20 kg N and 60 kg P_2O_5/ha, separately as well as in combination, proved optimum for most of the yield characteristics. The per cent increase in seed yield due to nitrogen (N_{20}) and phosphorus alone (P_{60}) over N_0 and P_0 was 20.5 and 21.0% respectively, while interaction (N_{20} x P_{60}) showed on increase of 33.4% over N_0xP_0.

Paricha et al. (1983) conducted a field trial during 1981-82 on green gram (Vigna radia L. Wilczek var. ML-131) to study the effect of inoculation, N-application and molybdenum. The soil was low in Mo status and N-fertility. The observed nodules in Mo treated plants were larger in size, more in number and contained higher amount of Mo. The N-concentration in the leaves was higher than the concentration in other plant parts. The reserve pool in the leaves contained more protein - nitrogen in Mo treated plants and accounted for 30% of the mobilised nitrogen to the pods. The nitrate reductase (NR) activity in the leaves of Mo treated plants was also higher. Mo application alone gave 26.4% more yield in the inoculated plants equalling 25 kg/ha of nitrogen fertilisation.

A field experiment was conducted by Raju and Varma (1984) during summer season of 1979 and 1980 on summer moong (Vigna radiata var. Pusa Baisakhi), to study the effect of Rhizobium inoculation in relation to fertiliser nitrogen application. Four levels of nitrogen in the form of urea, viz., 15, 30, 45 and 60 kg N/ha were applied in the presence and absence of Rhizobium inoculation. A uniform basal dose of 50 kg P_2O_5/ha was also given to all the treatments in the form of single superphosphate. There was significant improvement in nodulation in respect of nodule number and nodule dry weight per plant due to Rhizobium treatment alone or to Rhizobium in combination with 15 kg N/ha over the rest of the treatments. The same treatment produced maximum dry weight/plant, pod number/plant, 1,000 grain weight, protein yield and nitrogen uptake. Maximum grain yield of 853 kg/ha accounting for 39% increase over control was recorded by Rhizobium + 15 kg N/ha. It was also observed that application of nitrogen at higher levels either alone or in combination with Rhizobium depressed nodule formation.

In a factorial randomised field experiment, Akhtar *et al.* (1986) grew summer moong (*Vigna radiata* L. Wilczek var. T-44) with combined doses of nitrogen and phosphorus, with and without Rhizobium inoculation. There were two main plots, one with inoculation and the other without inoculation and six sub-plot treatments, i.e., $N_{10}P_{30}$, $N_{20}P_{30}$, $N_{10}P_{45}$, $N_{20}P_{45}$, $N_{10}P_{60}$ and $N_{20}P_{60}$. A uniform dose of potassium at the rate of (40 kg K_2O_5/ha) was also applied to all plots. Urea, monocalcium superphosphate and muriate of potash were used as sources of nitrogen, phosphorus and potassium respectively. Thus, in all there were twelve treatments each with three replications. Among sub-plot treatments, the response of the crop in relation to growth characteristics was not definite for any specific dose of fertiliser. However, yield parameters showed a clear pattern, with $N_{10}P_{60}$ giving maximum value for all the yield characteristics, except 1,000 seed weight which was maximum with $N_{20}P_{60}$. However, $N_{10}P_{60}$ was a close second to $N_{20}P_{60}$. When the differences between the main plot means at the same level of sub-plots were considered, it was found that most of the growth characteristics and all yield parameters gave higher value in the inoculated sub-plots than in the corresponding uninoculated sub-plots. When the values for the differences of sub-plot means at the same level of main plot treatments were examined for yield parameters, it was noted that $N_{10}P_{60}$ proved optimum and increased pod number/plant, pod length, 1,000 seed weight, pod weight and seed yield by 34.17, 19.81, 9.94, 28.63 and 64.25% respectively compared with the lowest dose ($N_{10}P_{30}$ with inoculum). However, for most of the growth parameters, $N_{20}P_{60}$ with inoculum proved better. On comparing the values for main plot means, significant response was noted with regard to growth as well as yield parameters. For most of the characteristics, inoculation gave higher values than the corresponding uninoculated plots. For yield parameters, inoculum increased pod number by 21.58%, pod length by 17.61%, 1,000 seed weight by 5.4%, pod yield by 12.30% and seed yield by 21.81% over no inoculation. The study also showed that, at 40 days (flowering stage), leaf number/plant, root nodule number/plant and dry weight/plant were positively correlated with seed yield. Correlation coefficient (r) being +0.580, +0.838 and +0.440 respectively. The same pattern was also found for pod number/plant, pod length, seed number/pod, 1,000 seed weight and pod yield (r = +0.89, +0.59, +0.61 and+0.91 respectively). Therefore, it was concluded that at least 60 kg P_2O_5/ha in combination with 10 kg N/ha may be applied basally with Rhizobium culture to moong under local conditions so as to get optimum returns.

Sekhon et al. (1986) conducted a pot culture experiment on moong (Vigna radiata) to study the effect of nitrogen on nitrate reductase activity in the nodules and leaves. They included various levels of nitrogen, viz., 0, 3, 6, 9 and 12 mg/kg in the form of urea, with uniform basal dose of 20 mg/kg phosphorus and 5 mg/kg Zn, in pots containing 8 kg of soil. The seeds were inoculated with appropriate Rhizobium culture. A control with uninoculated seeds and without nitrogen was also taken. At 26 days after sowing (DAS) nodules of the inoculated plants showed higher NR activity than those of the uninoculated plants. Therefore, the effect of various nitrogen levels was studied in inoculated plants only. It was observed that increasing concentrations of nitrogen upto 6 mg/kg significantly increased NR activity. Further increase in concentration decreased NR activity. The same trend was also found in leaves; but the NR activity was higher in the nodules. The soluble protein and NO_3^- contents were found to be highest at 6 mgN/kg, whereas, the maximum sugar content was noted in 3 mgN/kg. At 39 DAS, maximum NR activity was displayed by plants receiving 6 mgN/kg. The soluble protein and NO_3^- contents were maximum in 6 mgN/kg, but total sugar was maximum in 3 mgN/kg compared with preflowering stage (26 DAS). NR activity was considerably lower in both nodules and leaves at this stage than at preflowering stage. At pod development stage, i.e., 50 DAS, the maximum NR activity in leaves was observed in 3-6 mgN/kg, the total sugar were found to be maximum in 3 mgN/kg, whereas protein and NO_3^- contents were maximum in 6 mgN/kg. It was, therefore, concluded that for maximum NR activity, 3-6 mgN/kg was enough whereas, in the case of protein and NO_3^- contents, the best dose was 6 mgN/kg. The results revealed that NR activity was always higher in nodules than in leaves throughout the growth period in the presence of added nitrogen and that NR activity and protein, NO_3^- and total sugar contents decreased with the age of the plants.

Samiullah _et al_. (1987) conducted a field experiment on summer moong (_Vigna radiata_ L. Wilczek) var. K-851 according to split plot design to study the effect of nitrogen and phosphorus on its yield performance. The experiment comprised two main plots (10 and 20 kg basal N/ha) and four split-plots (30, 45, 60 and 75 kg of basal P_2O_5/ha). The sources of nitrogen and phosphorus were urea and monocalcium superphosphate respectively. A uniform dose of muriate of potash, at the rate of 40 kg K_2O/ha, was also applied to all plots. Thus, in all there were eight treatments each with three replications. The seeds were treated with _Rhizobium_ culture and were sown at the rate of 20 kg/ha. The crop received three irrigations between sowing and harvesting. Six yield attributes, namely, number of pods/plant, pod length, seed number/pod, 1,000 seed weight, pod yield and seed yield were studied at harvest. It was found that the effect of the treatments was significant only in the case of basal phosphorus (sub-plot treatments).

However, the interaction effect of nitrogen with phosphorus levels was also significant. All yield attributes except 1,000 seed weight (for which 60 kg P_2O_5/ha proved optimum), responded best to 75 kg P_2O_5/ha. It increased pod number/plant by 29.3%, pod length by 15.4%, seed number/pod by 22.00%, 1,000 seed weight by 2.5%, pod yield by 43.5% and seed yield by 41.4% compared with the lowest dose of phosphorus (30 kg P_2O_5/ha). When the difference of main plot means at the some level of sub-plot was considered, it was noted that generally sub-plot treatment getting 10 kg N/ha proved better than 20 kg N/ha. When the values for sub-plot means at the same level of main plot were taken into account, it was noted that 75 kg P_2O_5/ha x 10 kg N/ha gave the highest values for all the yield parameters, except 1,000 seed weight. It increased pod number/plant by 44.5%, pod length by 8.0%, pod yield by 46.4% and seed yield by 43.5% respectively, in comparison to 30 kg P_2O_5 x 10 kg N/ha.

2.4 Foliar application of fertilisers

For centuries farmers have found it profitable to add manures and other forms of decaying organic matter to their fields. With the advent of chemical fertilisers in the middle of the last century, their application to the soil for maintaning its fertility became equally liberal, particularly among the farmers of the advanced countries of Europe and America. However, the increasing cost of these fertilisers poses a grave problem for the poor farmers in developing countries. In fact, many of them are not able to apply the recommended basal dose of nutrients, due to economic constraints, at the initial growth stages of the crop. In addition, it has been observed that some of the added nutrients are rendered more or less unavailable to crop plants after their application owing to various reasons, including fixation, volatilisation, leaching and microbial decomposition. Critical studies have revealed that about 70% of soil-applied phosphorus (Russell, 1950) and 50% of nitrogen (Anonymous, 1971) is soon rendered unavailable to the crops. Therefore, several techniques have been adopted to overcome these problems. One of them is the conventional method of top dressing. However, it has proved difficult to adopt for several crops and is also wasteful to some extent like basal application. As a result, the national targets of food production have never been achieved fully in the recent past in our country. The novel technique of foliar application of nutrients seems to be a good alternative as it has proved a universally acceptable and economically sound practice for conveniently and efficaciously supplementing the fertiliser requirements of various standing crops at different stages of growth, particularly under adverse conditions. Other reasons that commend the adoption of this technique are :

1. Rapid loss of several nutrients in the soil makes them unavailable to the crop. The remedy for such " hidden hunger" in plants is to apply appropriate nutrients to the leaves in the form of dilute spray to the standing crop.

2. Slow response of plants to some soil-applied nutrients may often cause their deficiency which may be controlled by foliar application of the particular nutrient.

3. Some crops that remove large quantities of fertilisers during early vegetative growth consequently require nutrients as supplements at later stages when soil application generally becomes ineffective or cumbersome. For example, sugar cane requires additional nitrogen at later growth stages when the soil application of this nutrient becomes impractical (Ali, 1981). Such nutrient requirement is conveniently fulfilled by foliar application. Cereals (like wheat, barley and triticale), oil seeds, pulses and many other crops require nutrients at grain filling stage and the technique of foliar application of nitrogen and phosphorus has been found to increase the yield and improve the quality of seed in these crops (De, 1971; Afridi and Wasiuddin, 1979; Afridi, 1983; Sherchand and Paulsen, 1985; Samiullah *et al*., 1986).

4. The application of some micronutrients may be achieved successfully through foliar feeding. Boron and copper compounds seem to be readily absorbed and transported to all parts of the plant and one or two dilute sprays in a year elicit satisfactory response of the crop (Boynton, 1954).

5. Finally, foliar feeding is advantageous over soil application under hilly conditions and where soils are sandy and porous or highly alkaline, acidic or water-logged (Bould, 1963).

Forsyth was the first to note the significance of this technique in 1803 (Bould, 1963). However, the credit for the first published report (1844) has been accorded to Griss (Wittwer and Teubner, 1959). The research in this field has been facilitated since 1951 by the use of radio-isotopes which not only permit accurate measurements of the quantities of nutrients absorbed by the foliage but also of their subsequent translocation upto the root and shoot tips and other points of high metabolic activity (Silberstein and Wittwer, 1951; Wittwer and Lundahl, 1951; Wittwer and Bukovac, 1969).

The effectiveness of foliar nutrition depends on the ability of the applied nutrients first to penetrate through the cuticular cracks and the outer walls of epidermal cells. Once having penetrated through the cuticle, further movement of nutrients through the outer epidermal cell walls probably takes place mostly through the fine, thread like, submicroscopic structures called ectodesmata. When the substance reaches the plasma membrane of an epidermal cell, it is believed to be absorbed by mechanisms similar to those that operate in root cells (Noggle and Fritz, 1986).

After absorption through the leaves, the nutrients are transported to other plant parts, including roots. Transport of leaf-applied nutrients occurs via the phloem. The rate and amount of transport varies with each element. Williams (1955) and Baver (1963) reported that nitrogen moves to the places of metabolic demand rather than to the points of lowest concentration. Humbert (1968), however, found that movement of leaf-applied nutrients was from the region of high concentration to low concentration.

The uptake of leaf-applied nutrients and their translocation from the leaves is observed readily by changes in colour, composition, growth and yield of various organs of the plants. It is an "active" process dependent on temperature, light and oxygen supply. It is irreversible and occurs against concentration gradients and is influenced adversely by metabolic inhibitors. Some mineral nutrients, like calcium, magnesium, nitrogen, potassium, and zinc are absorbed very rapidly while others, like iron, molybdenum, phosphorus and sulphur are absorbed rather slowly as noted by Wittwer in 1964; Wittwer and Bukovac, 1969.

Absorption of nutrients by leaves and their subsequent metabolism are expected to vary largely with the plant type, species, leaf area, morphological stage, rate of growth, nutrient status, prevailing weather conditions, time of spraying and pH of spray solution (Wittwer and Teubner,1959; De, 1971).

Considerable work on commercial application of foliar spray of nutrients has been done abroad on vegetable (Mayberry, 1951; Montelaro et al., 1952; Martin, 1954; Wittwer, et al., 1957), fruit trees (Fisher and Walker, 1955), sugarcane (Burr et al., 1956) and sugar beet (Klechkovski, 1956; Thorne and Watson, 1956). In India also research on foliar nutrition of various crop has been undertaken by many workers (Anonymous, 1958; Kannan and Ranganathan, 1963; Ranganathan and Govinda, 1964; De et al., 1968). However, not much attention seems to have been paid to pulse crops. This is highlighted further by the following review of the meagre available literature on the foliar nutrition of this important group of crop plants.

Gorde and Kibe (1973) carried out a pot experiment in 1964-65 on China moong (Phaseolus aureus). They applied phosphorus through soil dressing as well as by foliar spray at different growth stages and also in various splits. The treatments were : (i) absolute control (without any treatment), (ii) phosphorus control (without phosphorus), (iii) soil dressing of 22.4 kg or 44.8 kg P_2O_5/ha), (iv) foliar application of 22.4 or 44.8 kg P_2O_5/ha in one single dose at 25, 35 or 40 days, in two equal split doses at various intervals of time viz., 25 and 35; 25 and 40; and 35 and 40 days and in three equal splits at 25, 35 and 40 DAS. All treatments, except absolute control, received a basal dose of 11.2 kg N/ha and 22.4 kg K_2O/ha. The plant samples were collected at 30 DAS and at maturity. N, P_2O_5 and K_2O contents were estimated in the leaves. In addition to these, grain yield/plant was also recorded. The data revealed that most of the treatments significantly increased N, P_2O_5 and K_2O contents of the plants at 30 DAS when compared with absolute control. Application of soil applied doses of phosphorus increased the N content in plants compared with absolute control but there was no significant difference with regard to the effect of the two doses (22.4 and 44.8 kg P_2O_5/ha). Regarding the effect of foliar application of nutrients, it was noted that leaf-applied phosphorus at 22.4 and 44.8 kg P_2O_5/ha either in one dose (25 DAS or in two equal doses (25 and 35 DAS) or in three equal split doses (25, 35 and 40 DAS) significantly increased the nitrogen content over absolute control. Maximum N and P_2O_5 contents were recorded with foliar spray of 44.8 kg P_2O_5/ha in two split doses applied at 35 and 40 DAS. When the values were compared with phosphorus control, foliar application of 22.4 and 44.8 kg P_2O_5/ha in one dose at 25 or two equal split doses at 25 and 35 or three equal split doses at 25, 35 and 40 DAS significantly increased the N, P_2O_5 and K_2O contents. On the other hand, the data at maturity, revealed that all the treatments significantly increased the nutrient contents over the control. When, 22.4 or 44.8 kg P_2O_5/ha was applied either through soil or through foliar spray in one dose at 25 DAS or in three equal splits at 25, 35 and 40 DAS, or foliar application of 22.4 kg P_2O_5/ha was sprayed in two equal split doses at 25 and 35 or at 25 and 40 DAS, it was revealed that N, P_2O_5 and K_2O contents were significantly increased over those of phosphorus control. With regard to the effect of the treatments on seed yield it was found that foliar application of 22.4 kg P_2O_5/ha at 25 DAS gave maximum seed yield, followed by the same amount of phosphorus sprayed in three instalments 25, 35 and 40 DAS.

Varma and Subba Rao (1974), working with *Phaseolus aureus* (Baisakhi moong), studied the effect of 2.5 and 5.0 per cent urea (applied to the tops of plants at 15 and 30 DAS on dry weight of shoot, dry weight of root, number of nodules, number of leaves, number of pods/plant and nitrogen content of leaves. The effect of this nutrient was observed under two conditions, i.e., with and without inoculum. The data revealed that inoculation increased all parameters studied. It was noted that the crop showed varied response to the spray treatments with regard to the different parameters. For example, dry weight of shoot and nitrogen content of leaves were increased due to both levels of spray treatment over uninoculated control, while leaf number and dry weight of roots were increased due to spray of 2.5% urea solution only over uninoculated control and these two parameters were adversely affected by spray of 5% urea solution. Root nodule number decreased due to spray. However, pod number/plant remained unaffected. It was interesting to note that, when the spray of urea was done on inoculated plants, all the parameters, except leaf nitrogen, were decreased compared with inoculated plants receiving no spray treatment. The study showed that spray of urea, particularly at low concentration, was more effective to promote the growth of the uninoculated plants while it had detrimental effect on the plants receiving inoculation.

Shrivastava and Verma (1981) studied the performance of green gram (Phaseolus aureus) during summer of 1977 and 1978. They applied three doses of phosphorus (20, 40 and 60 kg P_2O_5/ha) as a full soil dressing or as 1/2 soil and 1/2 foliar spray. Foliar application of phosphorus was done at 35 DAS and repeated at weekly interval using 10 kg P_2O_5/ha in each spray. They reported that methods of phosphorus application did not affect the performance of the crop significantly in relation to various parameters, including grain and straw yield.

Akhtar et al. (1984) studied the effect of foliar application of nitrogen and phosphorus on yield characteristics of lentil (Lens culinaris L. Medic.) var. T-36. They applied two basal doses of fertilisers, viz., full recommended dose (45 kg N + 70 kg P_2O_5 + 70 kg K_2O/ha) and half of it (22.5 kg N + 35 kg each of P_2O_5 and K_2O/ha). The seeds were treated with Rhizobiium culture. Aqueous solutions containing N and P_2O_5 at the rate of 10 kg N and 2 kg P_2O_5/ha were sprayed separately or in combination at both full and half basal levels. The controls at each level were sprayed with water. The trial was based on split-plot design and consisted of two main plots, each comprising eight sub-plots. One main plot was sprayed at 80 days (pre-flowering stage) and the other 110 DAS (pod initiating stage). Five yield attributes, namely, pod number/plant,pod length, seed number/pod, 1,000 seed weight and seed yield were studied at harvest (140 DAS). The effects of sub-plot and main plot treatments as well as of their interaction were found significant for all yield characteristics, except 1,000 seed weight. The data revealed that the crop showed equal response to the spray treatment with full basal dose and half basal dose giving no additional benefit of spray on full basal dose and thus proving uneconomical. Half basal dose with spray of 10 kg N + 2 kg P_2O_5/ha increased pod number/plant by 31.6%, pod length by 21.3%, seed number/pod by 15.4% and seed yield by 50.6% compared with its corresponding water-sprayed control. It was also noted that plants sprayed at 110 DAS showed good response for all characteristics. Thus, spray of 10 kg N + 2 kg P_2O_5/ha at half basal level gave about 4.0, 26.0, 13.0 and 50% increases for pod number/plant, pod length, seed number/pod and seed yield respectively over the control (sprayed with water at 110 days). It was also reported that pod number/plant, pod length, seed number/pod and 1,000 seed weight were positively correlated with seed yield, having correlation coefficient (r) = +0.951, +0.931, +0.915 and +0.814 respectively. On the basis of this study it was concluded that spray of 10 kg N + 2 kg P_2O_5/ha on plants grown with only half the basal recommended fertiliser dose at 110 DAS ensured maximum yield of lentil resulting in substantial fertiliser economy.

Samiullah et al. (1986) conducted a field experiment on mungbean (*Vigna radiata* L. Wilczek) cv. T-36 during summer season, in a simple randomised block design to study the effect of foliar application of phosphorus. The crop was grown with sub-optimal basal dose of 45 kg P_2O_5/ha as single superphosphate. A uniform basal dose of 10 kg N as urea and 40 kg K_2O/ha as muriate of potash was applied. Foliar application of 2, 4 or 8 kg P_2O_5/ha in the form of aqueous solution of sodium dihydrogen orthophosphate was done at flower initiation stage (35 DAS). Spray of deionised water at 45 kg P_2O_5/ha provided the control. To evaluate the economies of the technique, the optimal basal dose of phosphorus (60 kg P_2O_5/ha) was also included in the treatments. The seeds treated with *Rhizobium* inoculum were sown at the rate of 20 kg/ha. Harvesting was done twice (at 55 and 60 DAS) as the pods did not mature at the same time in this cultivar. All the parameters, except 1,000 seed weight were significantly affected by the spray treatments. Foliar application of 2 kg P_2O_5/ha at basal dose of 45 kg P_2O_5/ha proved optimum. This treatment gave the seed yield of 13.2 q/ha, while the spray of deionised water at 60 kg P_2O_5/ha had 11.6 q/ha yield. Thus, there was a net gain of 1.6 q/ha in seed yield accompanied by the saving of 13 kg P_2O_5/ha by the spraying only 2 kg P_2O_5/ha. The increase in seed yield due to this foliar treatment could be assigned to the cumulative ameliorating effect of yield parameters. This view was further supported by the correlation studies; as the significant positive values of correlation coefficient (r) were 0.59, 0.82, 0.85, 0.59 for pod number, pod length, seed number and 1,000 seed weight respectively against seed yield.

2.5 Vitamins

Vitamins are organic compounds required by living organisms in small amounts for normal growth. Their essentiality was realised first in animals and later in plants. McCollum and Davis (1915) discovered that young rats required certain chemicals for their sustained normal growth. These were later categorised as fat-soluble (A, D, E and K) and water-soluble (B and C) vitamins (Osborne and Mendel, 1915).

Vitamins are known to function as co-enzymes in the matebolism of both animals and plants. It is, therefore, reasonable to assume their essentiality in metabolism, which shows little variation in most plants. Strictly speaking, the vitamin requirement illustrates a pattern of metabolism and not a certain growth mechanism (Åberg, 1961). Wagner and Folkers (1964) defined vitamin as " an organic compound of natural food, distinct from macromolecules, essential for normal growth in small concentration, but when absent from diet causes deficiency symptoms" . The specific role of vitamins in animal metabolism is well understood, however, it has yet to be explored in plants to a large extent.

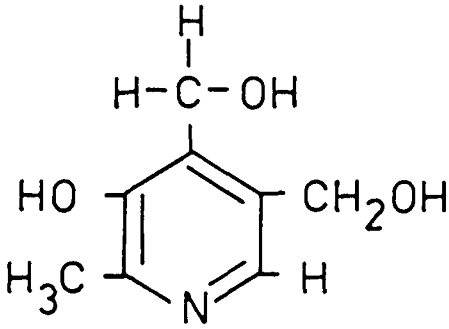
2.5.1 Vitamins of B-group

The water-soluble fraction of vitamins of McCollum and Davis (1915) and Osborne and Mendel (1915) was found to be a complex of related compounds. The vitamins isolated and indentified from this complex were designated arbitrarily and named as B_1 (thiamine), B_2 (riboflavin), B_3, B_4, B_5, B_6 (pyridoxine), B_7 (vitamin I), B_8 (adenylic acid), B_9, B_{10}, B_{11} and B_{12} (cyanocobalamine). Even though, these individual vitamins are now well known by their names or symbols, the term "vitamin B-complex" is still in vogue. Vitamins of this group together have been claimed as the growth factors for higher plants from time to time; but the most extensively studied among them are vitamin B_1 and B_6.

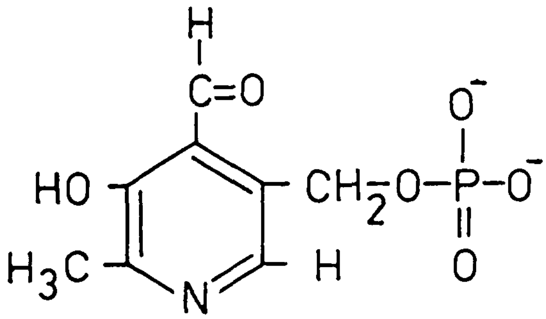
2.5.1.1 Vitamin B-6

A distinct entity of vitamin B_6 was first reported in animals by György (1934). However, after a few years, Keresztesy and Stevens (1938) and Kühn and Wendt in 1938 extracted and crystallised it from rice polishings and yeast extract respectively.

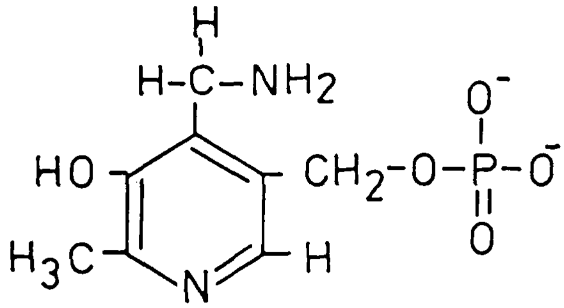
Harris and Folkers(1939), Harris *et al*. (1939) and Stiller *et al*. (1939) noted that pyridoxine ($C_8H_{11}O_3N$) is a pyridoxine derivative namely, 2-methyl-3-hydroxy-4,5-di-(hydroxymethyl)-pyridine, with the molecular structure as given in Fig.1(a). As free base, it is a colourless, crystalline



(a) PYRIDOXINE



(b) PYRIDOXAL PHOSPHATE



(c) PYRIDOXAMINE PHOSPHATE

FIGURE-1

powder with a slight bitter taste. It melts at 160°C and is readily soluble in water, alcohol and acetone. It is feebly destroyed by oxidising agents as well as by irradiation with visible or ultraviolet light. It crystallises in the form of various salts, e.g., hydrochloride (the marketable form) which is a white heat stable powder melting at 204-206°C (Keresztesy and Stevens, 1938). In this form it is readily soluble in water and alcohol.

Vitamin B_6 occurs in three active formsin living system, viz., pyridoxine, pyridoxal phosphate and pyridoxamine phosphate (Fig.1a,b and c). It is extremely versatile in function and is involved in transformation of amino acids and in transferring their amino groups. Thus, it acts as co-enzyme for transminases or amino-transferases(Lehninger, 1984).

It may be added here that although considerable work has been done on the metabolic role of pyridoxine in animals, the same can not be said about plants. Even information about its distribution and biosynthesis in plants is meagre. In view of this and on account of its close relationship with other members of the B-vitamins, it is proposed to review in the following pages the literature pertaining to the group as a whole with particular emphasis on pyridoxine because of the specificity of the present research problem.

Bonner and Devirian (1939) cultured excised roots of various plants in nutrient media. Isolated pea roots grew for an unlimited period in a medium containing vitamin B_1, nicotinic acid, mineral salts and sucrose at the rate of 70-85 mm/week. This growth rate remained unaltered even though various other chemical compounds including vitamin B_2, B_6, C, E, K, adenine, theelin, β-alanine, pantothenic acid and numerous amino acids were added. The rate of growth of isolated radish roots was 15 mm/week when they were grown through 15 passages in the presence of vitamin B_1 and nicotinic acid. These vitamins were found indispensable to maintain normal growth of the roots of these plants. The addition of other chemical compounds listed above was found ineffective. Similarly, excised flax roots responded only to vitamin B_1 and grew at the rate of 150 mm/week. On the other hand, excised roots of tomato showed a growth rate of 40 mm/week in the presence of vitamin B_1 and B_6. This rate was further enhanced up to 60 mm/week on supplementing the nutrient medium with nicotinic acid. These studies revealed that excised roots of various plants required different growth factors in the nutrient medium.

Robbins and Schmidt (1939a,b) found that addition of light brown sugar in nutrient medium was more beneficial for the growth of excised tomato roots than pure cane sugar. The root growth decreased when light brown sugar was replaced by its ash (treated with hydrochloric acid) or pure cane sugar containing nicotinic acid, nicotinamide, thiamine and amino acids. However, addition of pyridoxine (vitamin B_6) with pure cane sugar in the nutrient medium promoted the growth of tomato roots. Addition of pyridoxine also induced the development of hook and curls, indicating that it caused the elongation of cells. These observations showed that light brown sugar contained some root growth factor.

Bonner (1940) investigated root growth factor requirements of several plants *in vitro*. Excised roots of alfalfa, clover and cotton needed vitamin B_1 and nicotinic acid for their optimal growth, which did not improve further on the addition of vitamin B_6 in the nutrient medium. On the other hand, roots of *Datura stramonium* and sunflower showed profuse growth in the presence of vitamin B_1, B_6 and nicotinic acid. Similarly, isolated roots of carrot required vitamin B_1 and B_6 but the addition of nicotinic acid was of no use. In the case of five different strains of tomato, vitamin B_1 and B_6 proved beneficial for root growth which was further promoted by the inclusion of nicotinic acid in the medium. At the same time, excised roots of clover and flax were found to synthesise vitamin B_1 in small amounts. Therefore, they maintained sub-optimal growth even in the absence of this vitamin.

White (1940) observed the effect of vitamin B_6, nicotinic acid and pyridine in the presence of sufficient thiamine in nutrient medium, on the growth of excised roots of two tomato strains, Surprisingly, these strains of tomato did not significantly respond to vitamin B_6, nicotinic acid and pyridine. Therefore, he concluded that these strains of tomato did contain adequate amount of these substances to support the root growth under experimental condition.

Day (1941) successfully cultivated excised tomato roots on modified Pfeffer's solution containing agar-sucrose. Thiamine, pyridoxine, nicotinamide, neopeptone, glutamic acid and glycine were added in various combinations to this nutrient medium. In the presence of thiamine, roots grew about 2 mm daily which was further increased upto 5-6 mm or even more on addition of pyridoxine. However, supplementing this medium with nicotinamide did not alter the growth rate. It was noted that tomato roots could be cultivated through 20 passages (more than 200d), on the agar medium enriched with thiamine and pyridoxine without change in the growth rate. Further, presence of thiamine and pyridoxine in the agar medium induced the development of hooks and curls in the root. It was observed that pyridoxine could however, be replaced by glutamic acid or glycine.

Minnum (1941a) reported the effect of crystalline vitamin B_1, B_2 and B_6 and " Vita Flor" on the growth of cauliflower and radish in sand culture. Vita Flor contained 0.1% vitamin B_1, 0.5% nicotinic acid and traces of vitamin B_2, B_6 and pantothenic acid. These substances were given with Hoagland's nutrient solution plus trace elements. None of the treatments was found to have significant effect on the performance of these vegetables. Subsequently, in an extended field trial, Minnum (1941b) again found that crystalline vitamin, Vita Flor and brewer's yeast (containing vitamin B_1, B_2, B_6 etc.) did not exert beneficial effect on the yield of different vegetables, including beets, cauliflower, musk melon, pepper, radish, rutabages, snakebeans, summer squash, sweet corn and tomato.

Robbins (1941) studied the effect of various vitamin *in vitro* on root growth of two inbred tomato lines, viz., Red Current and Johannesfeur, and their heterotic F_1 generation. The roots were supplied with thiamine, thiamine and pyrdoxine or thiamine, pyridoxine and nicotinamide in the culture medium. These lines responded differentially to the vitamin application. The roots of F_1 produced more dry matter and showed better growth than either parent. However, the root growth of Red Current was luxuriant in the presence of thiazole which surpassed even the F_1 in one of the passages. It also responded better to nicotinamide than did Johannesfeur. The growth of Red Current became equal to that of hybrid F_1 if it was cultivated on a nutrient medium containing all the three vitamins. It seemed that the three lines of tomato had got different ability for thiamine, pyridoxine or nicotinamide synthesis which was presumably responsible for the variable effect of the application of these vitamins on their root growth. The maximum growth of hybrid F_1 roots was interpreted on this basis as they were supposed to have inherited characteristics of synthesising adequate amount of these vitamins cumulatively. On the other hand, better root growth of the hybrid in the medium containing all three vitamins was explained by assuming the higher synthesis of an unidentified growth factor in these roots.

Robbin (1942) investigated the effect of twelve analogues of pyridoxine on the growth of excised tomato roots in a medium supplemented with thiamine. Of these, nine analogues were found ineffective for root growth. Acetylation and substitution of ethyl for the methyl group in the second position of pyridine ring did not alter the beneficial activity of the vitamin. These studies thus indicated that pyridoxine had high degree of specificity for the growth of excised tomato roots.

Noggle and Wynd (1943) noted the effect of vitamins on germination and growth of orchid seeds. Orchid Cattleya trianeae var. mooreana and C. schrooderae seeds germinated and produced normal growth in an artificial nutrient medium when a lot of maltose was used; but there was no germination and seedling growth did not occure, when more purified maltose was used. This inhibitory effect was not overcome by the addition of thiamine hydrochloride (vitamin B_1), ascorbic acid (vitamin C) or calcium pantothenate (chick antidermatitis factor), when grown in the presence of purified maltose in growth medium. However, a few seeds germinated and slow developments of seedlings occurred when riboflavin (vitamin B_2)

was present in the medium. Further, they observed that the presence of pyridoxine (vitamin B_6) permitted good germination but poor seedling development, but good germination as well as excellent development of the seedlings occurred when nicotinic acid (P.P. factor) was supplied in the nutrient medium.

Hilderbrandt <u>et al</u>. (1946) worked out nutrient media for culturing tobacco and sunflower tissues. It was found that only sunflower tissue required pyridoxine in the basal medium for enhanced growth.

Almestrand (1950) studied the growth factor requirements of excised wheat roots. He included three vitamins, viz., niacin, thiamine and pyridoxine in the study. Of these, pyridoxine alone was found to be needed for the growth of wheat roots. It accelerated meristematic cell divisions. Addition of 0.5 to 1.0 mg pyridoxine/l of culture medium at 27-28°C proved optimum for wheat root growth.

Whaley <u>et al</u>. (1950) tested nutritional value of thiamine, niacin, and pyridoxine for the growth of excised tomato roots. White's solution, enriched with sucrose and glycine, was used as culture medium. The data revealed that these roots required thiamine and niacine or pyridoxine for their optimal growth. Moreover, thiamine acted synergistically both with niacin and pyridoxine.

Almestrand (1951) observed the effect of pyridoxine and its two derivatives on root growth of several strains of wheat, barley and oats as well as one of rye. No strain of barley, oats and rye responded to pyridoxine treatment, while different strains of wheat showed variable response to this vitamin. For instance, pyridoxine did not affect the root growth of Ergo II, Virtus and Pondus markedly but root growth of Eroica was considerably enhanced by pyridoxine application. He also noted that pyridoxine application enhanced the uptake of glucose, phosphate and nitrate in roots of the pyridoxine sensitive variety Eroica. The uptake of these substances corresponded to the dose of applied pyridoxine. Moreover, derivatives of pyridoxine, i.e., pyridoxal and pyridoxamine had similar beneficial effect to that of the mother compound.

Lee and Whaley (1953) cultured tomato roots for four weeks in two media : (a) without the supplementation of vitamins (b) supplemented with thiamine, niacin and pyridoxine individually or in combination. The data were collected at weekly intervals. Growth in all media was similar in the first week, but during the fourth week, the growth in all culture media declined. Therefore, the best period for investigation was considered to be second to third week. Optimum growth was recorded in the media containing thiamine alone or in combination with either of the other two vitamins, suggesting an interrelationship among these vitamins to support normal root growth.

Boll (1954) cultured excised tomato roots with the supplementation of vitamins to the nutrient medium. These roots required thiamine, pyridoxine and niacin for optimal growth. However, the growth could also be achieved if the medium contained only thiamine and pyridoxine. Moreover, pyridoxine and niacin in the medium were replaceable by pyridoxal or pyridoxamine and niacinamide respectively. It was also observed that niacinamide proved more active in comparison with niacin. Various derivatives of pyridoxine showed the order of effectiveness as pyridoxal > pyridoxine > pyridoxamine. Surprisingly, glycine was found to replace pyridoxine partly. This replacement become more effective in the presence of niacin. It was revealed that glycine and pyridoxine exerted similar morphological change in tomato roots. However, glycine affected initiation of lateral roots independently. These observations clearly established that a balanced supply of the growth substances in the basal medium determined the morphology of root.

Fujiwara and Ojima (1954) studied the effect of thiamine, pyridoxine and niacin on excised root tips of rice and wheat. The roots of these two plants responded positively to thiamine or pyridoxine application. However, in case of wheat, pyridoxine gave the best results. Moreover, application of vitamins did not show any effect on roots attached with their scutella. These roots grew much longer than excised roots.

Fries (1955a) compared the biosynthetic capabilities of decotylised pea seedlings grown in the dark with those of excised roots of the same plant. The decotylised pea seedlings required a mixture of water-soluble vitamins and various amino acids in sucrose-mineral salt medium for their optimum growth. Excised roots, on the other hand, remained unaffected by the application of these substances and attained a length of 150 mm even in the absence of the vitamins from which they inferred that excised roots had adequate reserve of vitamins. However, the roots ceased to grew after one or two transfers; but the growth was again maintained on supplying thiamine and niacin. In case of pea seedlings, the growth diminished very soon in a medium lacking the vitamins and the main root did not grow beyond 100 mm. The growth of the seedlings was further maintained by inclusion of thiamine and pyridoxine. However, niacin showed either poor or no effect. These studies showed that shoots failed to produce vitamins in the dark and consumed the vitamin reserves of the hypocotyl and young roots for their growth.

Fries (1955b) worked out the doses of thiamine and pyridoxine which could support the growth of decotylised pea seedlings in the dark on an agar-nutrient medium containing niacinamide and various amino acids. 10 μg of thiamine and 100 μg of pyridoxine/l were required to maintain normal growth of the seedlings. However, the pattern of growth and development of the seedlings was regulated independently by thiamine, pyridoxine, pyridoxine and niacin. It was also observed that, even in light, the added thiamine alone controlled the growth rate considerably, suggesting that the synthesis of thiamine in light could not keep pace with the optimum requirement of the seedlings.

Brusca and Haas (1957) studied the effect of several chemically pure salts of organic compounds on citrus grown in sand culture. Addition of vitamin B_6 (0.01 and 0.2 g/plant) and vitamin B_{12} (0.02 g/plant) to the nutrient solution stimulated the growth of citrus plants.

Barbieri (1959) performed a pot culture experiment on pea, broad bean, beet and wheat and observed that application of vitamin B_1 and B_6 enhanced plant height, leaf number, fresh weight and dry weight. The effect of both vitamins was most pronounced on beet and poorest on pea. For example, each of these vitamins at 0.01 mg/l increased the leaf number by 25% in beet seedlings compared with equal per cent in pea.

Vergnano (1959) tried vitamins B_1 and B_6 for improving the rooting in cuttings of some plants in sand culture. Each vitamin was added at the rate of 0.01 mg/l with the nutrient solution. Vitamin treatments did not improve rooting in *Colutea arborescens* but *Hedera helix* and *Rosa* showed good response. Treated plants of *Rosa* also produced greater number of buds and leaves with broader leaf blades than the controls.

Školník and Davydova (1962) applied 100 mg each of vitamin B_1 and B_6/1 to the roots of tomato plants. They observed that the application of these vitamins averted zinc deficiency symptoms in the plants to a large extent. The plants appeared similar to those which received zinc in their nutrition.

Kŭdrev and Pavlov (1965) averted ill effect of flooding at tillering, shooting and heading stages in wheat through foliar spray of vitamin B_6 solution. The spray of the vitamin solution also corrected disturbed nitrogen metabolism, particularly when very little damage had been done, and consequently enhanced the grain yield.

Das and Das (1966) observed the growth of excised pea roots as influenced by thiamine and pyridoxine treatments. They reported that these two vitamins showed similar growth promoting activity. However, the optimum dose of thiamine and pyridoxine differed, being 0.1 and 0.01 ppm respectively. It was pointed out that vitamins might become more effective in presence of mineral salts.

Dovydova (1966) observed the interrelationship between zinc and vitamins in the metabolism of tomato plants in soilless culture experiments. Zinc deficiency resulted in a slight reduction of pyridoxine content in roots of tomato plants; but the thiamine and riboflavin contents remained unaltered.

In addition, its deficiency also caused the accumulation of nitrate, which was lowered on supplying the plants with thiamine and pyridoxine. However, these vitamins did not affect the activity of nitrate reductase.

Ovcharov and Kulieva (1968) soaked cotton seeds in 0.01% pyridoxine solution for 1-3 h after which the seeds were sown with different forms of nitrogen and phosphorus fertilisers. In general, the vitamin slightly promoted germination and increased the area of first two- to three-fold. The effectiveness of vitamin B_6 depended upon the form of fertilisers used. Root length of treated seedlings in the presence of ammonium sulphate was 49% more than in untreated controls and was 14% less than in the presence of calcium nitrate. Pyridoxine increased the nitrogen and phosphorus contents in 2d old seedling. The increase in phosphorus content was more in the presence of potassium dihydrogen orthophosphate than in that of superphosphate. The soaking of seeds in the same concentration of nicotinic acid was effective irrespective of the type of the fertilisers.

Dimitrova-Russeva and Lilova (1969) studied the effect of the application of thiamine, pyridoxine and nicotinic acid on the uptake of nitrogen and phosphorus by Mentha piperita in nutrient solution as well as in soil. They found that uptake was increased by the application of these vitamins, phosphorus responding particularly to single application of nicotinic acid and double application of others. Nicotinic acid also enhanced the yield of essential oil as did two applications of thiamine, whereas pyridoxine reduced it.

Zavenyagina and Bukin (1969) investigated the effect of application of pyridoxine on the germination rate and growth of root and shoot of wheat and pea seedlings. Reduced germination rate and growth of root and shoot, showing the symptoms of vitamin B_6 avitaminosis, were eliminated to a great extent by the application of pyridoxine to the plants with nutrient medium. Chlorophyll content of leaves was also increased by the application of vitamin B_6 group (pyridoxal and pyridoxamine).

Kozin and Kravtsov (1973) supplemented the nutrient medium with pyridoxine to culture embryos of pear and apple. These embyos were isolated from seeds of different ripeness. They observed much higher germination, differentiation of embryo into seedling and accumulation of chlorophyll as a results of pyridoxine treatment. However, embryos from unripe seeds showed more pronounced response to pyridoxine than those of ripe seeds.

Gopala Rao _et al_. (1974) observed high succinic dehydrogenase activity in root and shoot, and enhanced respiration and protein synthesis in 4d old seedlings of _Phaseolus radiatus_ in a water culture experiment as a result of supplying the plants with biotin, pyridoxine, niacin and thiamine in the nutrient solution.

Pástena (1974) studied the rhizogenic action of some substances, viz., vitamins A, B_1, B_2, B_6, B_{12} and C on American vine cutting. The cuttings of the root stock were held for 24h in water solutions of vitamins, A, B_1, B_2 or B_6 at 125-2,500 ppm, B_{12} at 5-25 ppm or C at 150 to 25,000 ppm. The plants were planted in a nursery in March and examined during the following January and February. It was noted that vitamins A, B_2, B_{12} and C had negative effect on root formation and no effect on growth, compared to water treated control. However, vitamin B_1 and B_6, though having an inhibitory action on root formation, enhanced cutting growth leading to average cutting weight of 44-55g compared to 37g for the control.

Kulieva et al. (1976) investigated the response of melon and water-melon to vitamin treatments in laboratory and field conditions. Seeds of these plants were treated with various concentrations ranging from 0.01 to 0.0001% of thiamine, cyanocobalamine, nicotinic acid, pyridoxine or ascorbic acid. The effect of these compounds on stem and root development as well as on number and weight of fruit was studied in 45 and 90d old plants respectively. Generally, the best results were obtained by treating the seeds with thiamine (0.001%), cyanocobalamine (0.0001%) or nicotinic acid (0.0001%). However, beneficial results were obtained by spraying the plants with cyanocobalamine (0.001%) or ascorbic acid (0.01%) respectively.

Afridi <u>et al</u>. (1979) screened a number of common vitamins and phytohormones with respect to seed germination <u>in vitro</u> on radicle growth of barley and noted vitamin B_6 to be the most effective. On the basis of this preliminary trial, they performed an experiment on barley var.K672/28 in sand culture. Seeds of barley were soaked for 24h in 0.1, 0.3 and 0.5% aqueous pyridoxine solution and thereafter sown in pots. Treatment with pyridoxine benefitted most of the root, shoot and ear characteristics as well as grain yield and quality. Generally, soaking in 0.3 and 0.5% proved equally effective and optimum. Root length and number of lateral roots as well as leaf number were found to be 6.6, 19.0 and 13.5% more in 0.3% treatment than in the control. Tiller number/plant was at par in 0.3 and 0.5% pyridoxine treatments, being enhanced by 13% over the control. Treatment with 0.3% pyridoxine increased shoot length by 5.8% over the control with 0.5% following closely behind. Both these treatments consequently resulted in 15% more dry weight than in control. Similarly, other characteristics, including seed yield and seed carbohydrates were enhanced by 9.0 and 1.4% respectively by 0.3% treatment over the control; but straw yield was 12.7% more in 0.5% (at par with 0.3%) than the control.

Ahmad *et al*. (1981) studied the effect of soaking the seeds in different concentrations of pyridoxine solution (0.02, 0.10 and 0.50%) on tiller number, leaf number, fresh weight and dry weight per plant at heading and milky grain stages in five cultivars of barley, namely, NP-13, NP-21, K572/10, K-572/28 and Clipper in a factorial randomised field trial. Treatment with 0.1% proved optimum for these characteristics. Among various cultivars of barley, Clipper and K-572/28 produced maximum and minimum number of tillers and leaves respectively at all stages but the latter had the tallest plants, while NP-21 gave maximum fresh and dry weights. followed by K-572/28. Treatment x variety effect differed from character to character but the interaction 0.02% x K-572/28 in general proved the best.

Ahmad *et al*. (1982) reported their observations on grain and straw yields of the same barley varieties as in their earlier communication (Ahmad *et al*., 1981) as a result of seed treatment with pyridoxine. Grain and straw yields were recorded to be maximum in 0.1 and 0.02% treatments respectively. Similarly, K-572/28 and NP-21 gave highest grain and straw yields respectively. As far as interactions were concerned, the combination 0.1% x K-572/28 proved optimum for grain yield and 0.2% x NP-21 for straw yield. The net profit/ha due to 0.1% pyridoxine treatment was calculated to be Rs. 572.20.

In a field trial, Ashfaq et al. (1983) studied the effect of soaking the grains for 12h in 0.0, 0.1, 0.2, 0.3 and 0.4% aqueous pyridoxine solution on germination and yield characteristics of triticale var. Bronco-90. The vitamin treatment significantly affected most of the yield attributes. Among different treatments soaking in 0.2% proved optimum for example, this treatment enhanced grain yield by 37.7% presumably due to its beneficial effect on grain weight and per cent germination.

Ansari and Samiullah (1984) conducted a simple randomised field experiment on lentil (Lens culinaris L. Medic. T-36) to assess the effect of pyridoxine on different yield attributes. The seeds were soaked in water (I control) 0.1, 0.2, 0.3, 0.4 and 0.5% aqueous pyridoxine solution for 12h before sowing. Unsoaked seeds were also sown and were considered as II control. At harvest, 0.3% pyridoxine solution proved optimum for pod number/plant, seed number/pod and seed yield. However, pod length was unaffected and 1,000 seed weight was decreased.

Khan and Ansari (1984), working with Phaseolus radiatus, found that soaking of seeds for 10h in graded pyridoxine solutions (0.0, 0.1, 0.2 and 0.3%) stimulated the growth of 10d old seedlings (two leaf stage) in sand culture. Soaking in 0.1% solution enhanced the fresh weight and number of lateral roots by 18.2 and 23.8% respectively over the water-soaked control.

Kodandaramaiah and Gopala Rao (1984) observed the influence of B-vitamins on photosynthesis of isolated chloroplast of Cyamopsis tetragonoloba CL. Taub. They noted that thiamine, riboflavin, niacin, pyridoxine, pantothenic acid and folic acid, at concentrations varying from 50-200 mg/l, significantly increased photosynthetic carbon fixation by isolated chloroplasts. However, direct action of the vitamins above 5 mg/l concentration in vitro diminished carbon fixation. The maximum promotion was noticed by niacin (51.0%) followed by pyridoxine (44.9%).

Raghava Reddy and Gopala Rao (1984) noted the influence of citric acid and pyridoxine on flowering in Brassica nigra Koch, and found that these two vitamins induced early flowering in black mustard. They concluded that this was due to the increase in the leaf area and height of plant.

Gopala Rao and Raghava (1985) observed the effect of B-vitamins on the uptake of sodium, potassium, calcium and phosphorus in one week old Vigna radiata seedlings. Treatment with the vitamins promoted the uptake of these elements variably. Thiamine and biotin were found ineffective in the uptake of phosphorus; but riboflavin, pyridoxine and pantothenic acid increased the uptake of sodium, potassium and calcium in addition to that of phosphorus by the seedlings. Application of pyridoxine,pantothenic acid and nicotinic acid particularly showed more influence on potassium and phosphorus uptake than the other vitamins included in the study.

Samiullah et al. (1985) conducted two simple randomised field experiments to study the effect of pyridoxine treatment on root length, root nodule number, nitrate reductase activity (NRA) and yield of Vigna radiata var. K-851. In the first experiments, seeds of Vigna radiata were soaked for 4h in 0.0 (control), 0.1, 0.2, 0.3, 0.4 and 0.5% aqueous pyridoxine solution. Root length, root nodule number and NRA were measured at 20, 30, 40 and 50 DAS. It was found that, at 20 and 30d, maximum root length was obtained in 0.2% and 0.3% treatments. giving 12.9 and 36.7% more values than the respective controls. At 40 and 50d, maximum root length was noted in 0.4% treatment and gave an increase of 20.2 and 25.1% over the respective controls. Moreover, root nodule number at 30, 40 and 50d was optimum in 0.3% showing an increase of 144.0 and 25.1 and 25.3% over the respective controls. Soaking in 0.3% increased NRA by 29.7, 7.1, 11.8 and 15.6% at 20, 30, 40 and 50d over the respective controls. Seed yield was maximum in 0.3%, which was 54.9% more than the control. In an other experiment the same concentrations of pyridoxine solution were sprayed on leaves either at pre-flowering (35d) or post flowering (45d) stage. Root length, root nodule number and NRA were measured at 45 and 55 DAS (10d after spray). For control, plants were sprayed with deionised water. It was noted that spray of 0.1%

pyridoxine solution at pre-flowering stage (35 DAS) proved optimum and enhanced root nodule number and NRA by 17.8 and 49.2% over their respective controls. At post-flowering stage (45 DAS) spray of 0.2% pyridoxine solution gave optimum value for root length and NRA (45.4 and 29.6% respectively more than the control). The increase in yield by 0.1 and 0.2% spray at pre-flowering (35 DAS) and post-flowering stage (45 DAS) was 33.7 and 26.4% respectively over the respective controls. On comparing the data of both experiments, it was concluded that soaking of seeds in pyridoxine solution was more effective than spraying the vitamin over the leaves. Seed treatment required a smaller quantity of the vitamin than spraying the same population of plants. It was suggested by the authors that seed treatment with dilute pyridoxine solution may be exploited commercially as a simple, convenient and economical farm practice for ensuring high productivity.

Ahmad et al. (1986a) carried out a factorial randomised field trial to study the effect of pre-sowing soaking of seeds on yield attributes of five barley varieties, namely, NP-13, N-21, N-572/10, K-572/28 and Clipper in 0.0, 0.02, 0.10 or 0.5% aqueous pyridoxine hydrochloride solution for 24h. The parameters studied were ear number/plant, ear length, spikelet number/ear, grain number/ear and grain and straw yield/ha. It was noted that pyridoxine significantly affected the ear weight/plant and grain yield/ha showing an increase of

10.4 and 10.6% over the control in 0.1% solution and 4.8 and 5.3% increase over the control in 0.02% solution. However, ear number/plant and straw yield/ha were maximum in 0.02% treatment, showing an increase of 3.4 and 11.2% over the control; but grain number/ear was equally affected by all concentrations of pyridoxine hydrochloride solution. Varieties K-572/28 and NP-21 showed maximum value for grain and straw yield respectively. The combination 0.02% x K-572/28 gave the best response for most attributes, including grain yield.

Ahmad et al. (1986b) studied the effect of pre-sowing grain treatment of pyridoxine on test weight, carbohydrate content and protein content of five barley varieties, namely, NP-13, NP-28, K572/10, K572/28 and Clipper. Seeds were soaked for 24h in 0.0, 0.02, 0.10 and 0.50% aqueous pyridoxine solution. Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) was given uniformly at the rate of 80, 30 and 40 kg/ha respectively. They reported that soaking of barley grains in pyridoxine solution enhanced 1,000 grain weight, grain protein content. Grain carbohydrate and protein contents/ha were maximum in 0.1% treatment. However, grain carbohydrate content decreased in 0.50% pyridoxine solution. Among varieties, K-572/28 surpassed all others in these characteristics. The combination 0.1% x K-572/28 gave maximum response.

In a simple randomised field trial, Ansari and Khan (1986) observed the effect of pre-sowing seed treatment for 4h with graded aqueous pyridoxine solution (0.0, 0.1, 0.2, 0.3, 0.4 and 0.5%) on the growth and yield performance of summer moong. They observed that 0.3% pyridoxine solution significantly enhanced plant length, leaf number, fresh weight and dry weight at 30, 40, and 50d growth; NAR for 20-30, 30-40 and 40-50d growth and pod number/plant, pod length and seed number/pod at harvest. Seed yield was positively correlated with plant length at 30 and 50d with leaf number and dry weight at 30, 40 and 50d, with fresh weight at 30 and 40d and with NAR at all intervals. Seed protein content showed positive correlations with plant length at 30, 40 and 50d, with fresh weight and dry weight at 40 and 50d, and with NAR for 30-40 and 40-50d. However, pod number, pod length, and seed number/pod were correlated with seed yield only.

Oertli (1987) reviewed the literature on plant responses to the exogenous applications of vitamins. He summarised that :

Vitamins have been applied by soaking seeds or dipping cuttings; by spray or dusts or as drenches to soils. Substantial yield increase due to exogenous vitamin application has been reported by a number of researchers. Vitamins may cause morphogenetic response in plants. The stimulation of root formation and flowering under non-inductive conditions are the most pronounced among these responses. Certain vitamins protect plants against ozone and sulfur dioxide, two important agents of air pollution.

2.6 Concluding remarks

The foregoing review clearly establishes that pyridoxine (vitamin B_6) is a potent root growth promoting substance *in vitro* and *in vivo* for many crops. In some cases, pyridoxine has been shown to stimulate nutrient uptake. This opens up a new area of research in which the interaction of pyridoxine with the applied nutrients could be exploited for increasing the productivity and quality of food crops particularly This also applies to grain legumes which are not only the chief source of vegetable proteins but are also mainly responsible for fixing dinitrogen in arable land. However, this aspect of legume productivity has not hitherto been touched by scientists. The research work reported in the subsequent chapters is related to this aspect in order to fill the existing lacuna in our understanding of pyridoxine-nutrient relationship in augmenting the performance of leguminous crops.

CHAPTER 3

MATERIALS AND METHODS

CONTENTS

MATERIALS AND METHODS

MATERIALS AND METHODS

The field experiments on lentil (Lens culinaris L. Medic.) var. T-36 reported and discussed in this thesis, were conducted in the "rabi" (winter) seasons of 1984-85 and 1985-86 and those on summer moong (Vigna radiata L. Wilczek) var. K-851, in the "zaid" (summer) seasons of 1985 and 1986 at the University Farm of the Aligarh Muslim University, Aligarh (U.P.) India.

3.1 Agro-climatic conditions

Aligarh is one of the sixty one districts of Uttar Pradesh (Northern India). It has an area of 5.02×10^{9} sq.m. and is situated at 27°52'N latitude, 78°51'E longitude and 187.45 m altitude. Its climate is characteristic of western Uttar Pradesh, i.e., semi-arid and sub-tropical, with hot dry summers and cold winters. The winter extends from the middle of October to the end of March. The mean temperature for December and January, the coldest months, is about 15°C and 13°C and the extreme minimum record for any single day is 2°C and 0.5°C respectively. The summer is hot, the average temperature for May is 34.5°C and for June 34°C whereas, the extreme maximum record is 45°C and 45.5°C. The average annual rainfall is 847.3 mm. More than 85% of the total rainfall occurs during June-September and some 10% in the winter which benefits " rabi" crops (data recorded at the Meteorological Observatory, Department of Physics, Aligarh Muslim University, Aligarh).

Aligarh district possesses various types of soil, like sandy, loamy, sandy loam and clayey loam.

3.2 Soil characteristics

Before sowing, soil samples were collected from each plot upto a depth of about 10-15 cm. These were mixed thoroughly to get a composite sample. The composite sample was analysed in the Soil Chemistry Laboratory of the Indian Agricultural Research Institute (I.A.R.I.), New Delhi. The physico-chemical properties of the soil for each experiment have been given in Table 1.

3.3 Field preparation

Prior to each trial, the experimental field was thoroughly ploughed to ensure maximum soil aeration. It also helped in eliminating the weeds. Plots of 5 sq.m. size were prepared for each treatment and irrigated lightly before sowing to maintain proper moisture regime in the sub-surface of the soil. The crop (lentil or moong) was cultivated according to standard agricultural practices. A uniform basal dose of potassium as recommended for each crop was broadcast in each plot to maintain the potassium requirement of the crop.

Table 1. Physico-chemical characteristics of surface soil of the fields used for Experiments 1-8

Characteristics	Years							
	1984-85	1984-85	1985-86	1985-86	1985	1985	1986	1986
	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Experiment 6	Experiment 7	Experiment 8
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Particle size distribution								
Sand %	73.20	73.00	73.16	72.86	73.00	73.20	72.86	73.00
Silt %	7.86	7.84	8.23	8.26	7.69	7.85	8.43	8.22
Clay %	19.43	19.36	18.75	18.76	17.88	17.98	19.22	19.41
pH (1:2)	7.84	7.86	8.04	8.08	7.90	7.92	7.66	7.68
Conductivity E.C. (1:2) (m mhos/cm)	0.46	0.39	0.48	0.48	0.38	0.38	0.44	0.45
Available nitrogen (kg N/ha)	223.34	219.56	230.35	226.46	234.56	236.66	240.22	242.42
Available phosphorus (kg P/ha)	18.33	18.34	19.44	19.48	18.86	18.89	18.64	18.63
Available potassium (kg K/ha)	690.64	688.55	668.29	681.66	684.78	675.98	680.49	682.75

3.4 Seed treatment

Authentic seeds of lentil and moong were obtained from the National Seed Corporation, I.A.R.I., New Delhi and their viability was tested by standard methods. The seeds, were surface sterilised and soaked in water (control) or in appropriate pyridoxine hydrochloride solution prior to inoculation with Rhizobium, using the method of Subba Rao (1972) with the following modifications. Rhizobium culture for lentil and moong was obtained from the Government Seed Store, Aligarh. The inoculum was prepared by dissolving 400g colourless gum-arabic (coating material) and 100g sugar in 1l warm water. The solution was allowed to cool and a packet of Rhizobium culture (containing 200g bacterial culture in peat) was added to it and mixed well, resulting in a muddy solution. It was used to inoculate 10kg seeds of either lentil or moong depending upon the nature of the bacterial culture mixed in the inoculum medium. Seeds were vigorously mixed with the inoculum until they were evenly covered and moistened by it. These inoculated seeds were spread on a clean blotting paper in shade to let the coating get hard. Thereafter, they were sown in the field.

3.5 Experiments on lentil

Four experiments were conducted on lentil (Lens culinaris L. Medic.) var. T-36 during "rabi" seasons of 1984-85 and

1985-86. Of these, the first two experiments were conducted simultaneously in 1984-85 and the last two in the next "rabi" season, i.e., 1985-86.

3.5.1 Experiment 1

The aim of this trial was to investigate the effect of four basal levels of nitrogen, pre-sowing seed treatment with four aqueous concentrations of pyridoxine alone and of their interaction on growth and yield performance of lentil. The basal doses of nitrogen and range of concentrations of pyridoxine solution and the optimum period required for soaking were selected on the basis of reports of earlier workers in the author's laboratory (Akhtar, 1985; Ansari, 1986).

Basal nitrogen at 15, 30, 45 and 60 kg N/ha, together with a uniform recommended basal dose of phosphorus (45 kg P/ha) and potassium (30 kg K/ha) was applied to the field before sowing. The sources of nitrogen, phosphorus and potassium were urea, monocalcium superphosphate and muriate of potash respectively. Seeds of uniform size were sterilised with ethyl alcohol. Sufficient seeds were soaked for 12h in 0 (control), 0.2, 0.3 and 0.4% aqueous pyridoxine hydrochloride solution. The soaked seeds were kept in separate conical flasks. Thereafter, seeds were inoculated with Rhizobium as described on earlier (p. 90). Soaked-seeds were sown behind the plough in eight rows in 5 sq.m. plots at the rate of 50 kg/ha on November 8, 1984. The rows were 25 cm apart and the number of seeds in each row was kept uniform as far as possible. Each treatment was replicated thrice. The experiment was laid out according to factorial randomised block design (Table 2). The crop received two irrigations between sowing and harvesting. Weeding was done once during the entire course of crop development.

Plants were sampled at 60, 90 and 120d after sowing for assessing the growth performance of the crop. At harvest (140 DAS), various yield parameters and seed yield and quality were studied.

3.5.2 Experiment 2

This experiment on lentil was conducted simultaneously with Experiment 1. The physico-chemical properties of the soil are given in Table 1.

The object of the experiment was to study the phosphatic fertiliser utilisation efficiency of lentil (as assessed by the growth, yield and quality performance of the crop) under varying levels of pre-sowing seed treatment with pyridoxine.

The seeds were soaked for 12h in pyridoxine solution and inoculated with *Rhizobium*. The treated seeds were sown behind the plough in eight rows in 5 sq.m. plots at the rate of 50 kg/ha on November 15, 1984. There were sixteen treatments

Table 2. Scheme of treatments for Experiment 1 on lentil (Factorial randomised)

Sl. No.	Combinations Basal (B) x Soaking (S)	Basal treatments	kg N/ha	Soaking treatments	% pyridoxine solution
1.	B_{N15} x S_W	B_{N15}	15	S_W	0.0
2.	B_{N15} x S_1	B_{N15}	15	S_1	0.2
3.	B_{N15} x S_2	B_{N15}	15	S_2	0.3
4.	B_{N15} x S_3	B_{N15}	15	S_3	0.4
5.	B_{N30} x S_W	B_{N30}	30	S_W	0.0
6.	B_{N30} x S_1	B_{N30}	30	S_1	0.2
7.	B_{N30} x S_2	B_{N30}	30	S_2	0.3
8.	B_{N30} x S_3	B_{N30}	30	S_3	0.4
9.	B_{N45} x S_W	B_{N45}	45	S_W	0.0
10.	B_{N45} x S_1	B_{N45}	45	S_1	0.2
11.	B_{N45} x S_2	B_{N45}	45	S_2	0.3
12.	B_{N45} x S_3	B_{N45}	45	S_3	0.4
13.	B_{N60} x S_W	B_{N60}	60	S_W	0.0
14.	B_{N60} x S_1	B_{N60}	60	S_1	0.2
15.	B_{N60} x S_2	B_{N60}	60	S_2	0.3
16.	B_{N60} x S_3	B_{N60}	60	S_3	0.4

N.B.(1) Seeds were soaked for 12h and then treated with rhizobium inoculum

(2) A uniform basal dose of 45kg P and 30 kg K/ha was applied

each replicated thrice (Table 3). A uniform basal dose of 45 kg N/ha and 30 kg K/ha was applied. Other agricultural practices were kept as in Experiment 1.

Plants were sampled at 60, 90 and 120d after sowing for assessing the growth performance of the crop. At harvest (140d) various yield parameters and seed yield and quality were studied.

3.5.3 Experiment 3

This field trial was conducted in the next year, i.e., "rabi" season of 1985-86. The soil characteristics of the field are given in Table 1.

The trial was based on the findings of Experiment 1. The object of the experiment was to investigate the individual and combined effectsof foliar spray of supplemental nitrogen applied with optimal or sub-optimal basal doses of this nutrient together with that of pre-sowing seed treatment with pyridoxine.

The experiment was conducted according to factorial randomised block design and comprised twelve combinations of treatments (Table 4). Each treatment was replicated thrice. The seeds were soaked for 12h in 0.2 and 0.3% aqueous pyridoxine solution and later inoculated with Rhizobium prior to sowing. A uniform basal dose of 30 kg P and K/ha each was applied to every plot. Supplemental nitrogen as aqueous solution of urea

Table 3. Scheme of treatments for Experiment 2 on lentil (Factorial randomised)

Sl. No.	Combinations Basal (B) x Soaking (S)	Basal treatments	kg P/ha	Soaking treatments	% pyridoxine solution
1.	B_{P15} x S_W	B_{P15}	15	S_W	0.0
2.	B_{P15} x S_1	B_{P15}	15	S_1	0.2
3.	B_{P15} x S_2	B_{P15}	15	S_2	0.3
4.	B_{P15} x S_3	B_{P15}	15	S_3	0.4
5.	B_{P30} x S_W	B_{P30}	30	S_W	0.0
6.	B_{P30} x S_1	B_{P30}	30	S_1	0.2
7.	B_{P30} x S_2	B_{P30}	30	S_2	0.3
8.	B_{P30} x S_3	B_{P30}	30	S_3	0.4
9.	B_{P45} x S_W	B_{P45}	45	S_W	0.0
10.	B_{P45} x S_1	B_{P45}	45	S_1	0.2
11.	B_{P45} x S_2	B_{P45}	45	S_2	0.3
12.	B_{P45} x S_3	B_{P45}	45	S_3	0.4
13.	B_{P60} x S_W	B_{P60}	60	S_W	0.0
14.	B_{P60} x S_1	B_{P60}	60	S_1	0.2
15.	B_{P60} x S_2	B_{P60}	60	S_2	0.3
16.	B_{P60} x S_3	B_{P60}	60	S_3	0.4

N.B.(1) Seeds were soaked for 12h and then treated with rhizobium inoculum

(2) A uniform basal dose of 45 kg N/ha and 30 kg K/ha was applied

Table 4. Scheme of treatments for experiment 3 on Lentil (Factorial randomised)

Sl. No.	Combinations Basal (B) + Foliar (F) x Soaking (S)	Basal treatments kg N/ha	Foliar treatments kg N/ha	Soaking treatments	% pyridoxine solution
1.	$(B_{N15} + F_W) \times S_1$	B_{N15} = 15kgN/ha	F_W = (deionised water spray)	S_1	0.2
2.	$(B_{N15} + F_W) \times S_2$	B_{N15} = 15kgN/ha	F_W = ''	S_2	0.3
3.	$(BN_{30} + F_W) \times S_1$	B_{N30} = 30kg N/ha	F_W = ''	S_1	0.2
4.	$(B_{N30} + F_W) \times S_2$	B_{N30} = 30 kg N/ha	F_W = ''	S_2	0.3
5.	$(B_{N15} + F_{N5}) \times S_1$	B_{N15} = 15 kg N/ha	F_{N5} = (5kg N/ha spray)	S_1	0.2
6.	$(B_{N15} + F_{N5}) \times S_2$	B_{N15} = 15 kg N/ha	F_{N5} = ''	S_2	0.3
7.	$(B_{N30} + F_{N5}) \times S_1$	B_{N30} = 30 kg N/ha	F_{N5} = ''	S_1	0.2
8.	$(B_{N30} + F_{N5}) \times S_2$	B_{N30} = 30 kg N/ha	F_{N5} = ''	S_2	0.3
9.	$(B_{N15} + F_{N10}) \times S_1$	B_{N15} = 15 kg N/ha	F_{N10} = (10kg N/ha spray)	S_1	0.2
10.	$(B_{N15} + F_{N10}) \times S_2$	B_{N15} = 15 kg N/ha	F_{N10} = ''	S_2	0.3
11.	$(B_{N30} + F_{N10}) \times S_1$	B_{N30} = 30 kg N/ha	F_{N10} = ''	S_1	0.2
12.	$(B_{N30} + F_{N10}) \times S_2$	B_{N30} = 30 kg N/ha	F_{N10} = ''	S_2	0.3

N.B.(1) Seeds were soaked for 12h and then treated with rhizobium inoculum

(2) A uniform basal dose of 30kg P and 30 kg K/ha was applied

(3) Foliar treatments were given at 100d

was applied to the leaves at pod filling stage, i.e., at 100d. Other agricultural practices, including irrigation, weeding etc., were similar to those in the Experiment 1. Plants from each plot were collected at 120d for assessing growth performance. At harvest (140d) yield parameters and seed yield and quality were studied.

3.5.4 Experiment 4

This field trial was conducted simultaneously along with Experiment 3, i.e., in the "rabi" season of 1985-86. The soil characteristics of the field are given in Table 1.

The trial was based on the findings of Experiment 2. The object of the experiment was to investigate the individual and combined effects of foliar spray of phosphorus and pyridoxine soaking together with optimal and sub-optimal basal doses of phosphorus.

The experiment was conducted according to factorial randomised block design with twelve combinations of treatments (Table 5). Each treatment was replicated thrice. The seeds were soaked for 12h in aqueous pyridoxine solution and later inoculated with *Rhizobium*. Prior to sowing, a uniform basal dose of 30 kg N and K/ha each was applied to every plot. Foliar spray of phosphorus (as decanted aqueous solution of monocalcium superphosphate) was done at pod filling stage (100d). Other agricultural practices, including irrigation, weeding etc.,

Table 5. Scheme of treatments for experiment 4 on Lentil (Factorial randomised)

Sl. No.	Combinations Basal (B) + Foliar (F) x Soaking (S)	Basal treatments kg P/ha	Foliar treatments kg P/ha	Soaking treatments	% pyridoxine solution
1.	$(B_{p20} + F_W) \times S_1$	B_{P20} = 20kg P/ha	F_W = (deionised water spray)	S_1	0.2
2.	$(B_{P20} + F_W) \times S_2$	B_{P20} = 20kg P/ha	F_W = ''	S_2	0.3
3.	$(B_{P30} + F_W) \times S_1$	B_{P30} = 30kg P/ha	F_W = ''	S_1	0.2
4.	$(B_{P30} + F_W) \times S_2$	B_{P30} = 30kg P/ha	F_W = ''	S_2	0.3
5.	$(B_{P20} + F_{P1}) \times S_1$	B_{P20} = 20kg P/ha	F_{P1} = (1kg P/ha spray)	S_1	0.2
6.	$(B_{P20} + F_{P1}) \times S_2$	B_{P20} = 20kg P/ha	F_{P1} = ''	S_2	0.3
7.	$(B_{P30} + F_{P1}) \times S_1$	B_{P30} = 30kg P/ha	F_{P1} = ''	S_1	0.2
8.	$(B_{P30} + F_{P1}) \times S_2$	B_{P30} = 30kg P/ha	F_{P1} = ''	S_2	0.3
9.	$(B_{P20} + F_{P2}) \times S_1$	B_{P20} = 20kg P/ha	F_{P2} = (2kg P/ha spray)	S_1	0.2
10.	$(B_{P20} + F_{P2}) \times S_2$	B_{P20} = 20kg P/ha	F_{P2} = ''	S_2	0.3
11.	$(B_{P30} + F_{P2}) \times S_1$	B_{P30} = 30kg P/ha	F_{P2} = ''	S_1	0.2
12.	$(B_{P30} + F_{P2}) \times S_2$	B_{P30} = 30kg P/ha	F_{P2} = ''	S_2	0.3

N.B.(1) Seeds were soaked for 12h and then treated with rhizobium inoculum

(2) A uniform dose of 30kg N/ha and 30kg K/ha was applied

(3) Foliar treatments were given at 100d

were kept similar to the previous experiments. Three plants from each plot were collected randomly at 120d for assessing growth performance. At harvest (140d) yield parameters and seed yield and quality were studied.

3.6 Experiments on moong

Four field experiments were conducted on moong (*Vigna radiata* L. Wilczek) var.K-851 at the University Farm, two each during " zaid" season of 1985 and 1986 respectively.

3.6.1 Experiment 5

The aim of this experiment was to investigate the effect of basal application of nitrogen and pre-sowing seed treatment with pyridoxine as well as of their interaction on growth, yield and quality performance of summer moong in a factorial randomised block design. The physico-chemical properties of the soil are given in Table 1. The concentrations of pyridoxine solution and period for pre-sowing seed treatment as well as the doses of basal nitrogen fertiliser were selected according the experience gained earlier in the author's laboratory (Akhtar, 1985; Samiullah *et al.*, 1985). There were thus, sixteen combinations of four doses basal nitrogen fertiliser with four pyrixoxine soaking treatments (Table 6). Each treatment was replicated thrice.

After soaking for 4h in aqueous pyridoxine solution, the seeds were inoculated with *Rhizobium* (Section 3.4) and sown

Table 6. Scheme of treatments for experiment 5 on Summer moong (Factorial randomised)

Sl. No.	Combinations Basal (B) x Soaking (S)	Basal treatments	kg N/ha	Soaking treatments	% pyridoxine solution
1.	$B_{NO} \times S_W$	B_{NO}	0	S_W	0.0
2.	$B_{NO} \times S_1$	B_{NO}	0	S_1	0.2
3.	$B_{NO} \times S_2$	B_{NO}	0	S_2	0.3
4.	$B_{NO} \times S_3$	B_{NO}	0	S_3	0.4
5.	$B_{N5} \times S_W$	B_{N5}	5	S_W	0.0
6.	$B_{N5} \times S_1$	B_{N5}	5	S_1	0.2
7.	$B_{N5} \times S_2$	B_{N5}	5	S_2	0.3
8.	$B_{N5} \times S_3$	B_{N5}	5	S_3	0.4
9.	$B_{N10} \times S_W$	B_{N10}	10	S_W	0.0
10.	$B_{N10} \times S_1$	B_{N10}	10	S_1	0.2
11.	$B_{N10} \times S_2$	B_{N10}	10	S_2	0.3
12.	$B_{N10} \times S_2$	B_{N10}	10	S_3	0.4
13.	$B_{N15} \times S_W$	B_{N15}	15	S_W	0.0
14.	$B_{N15} \times S_1$	B_{N15}	15	S_1	0.2
15.	$B_{N15} \times S_2$	B_{N15}	15	S_2	0.3
16.	$B_{N15} \times S_3$	B_{N15}	15	S_3	0.4

N.B.(1) Seeds were soaked for 4h and then treated with rhizobium inoculum

(2) A uniform basal dose of 30 kg P and 35 kg K/ha was applied

behind the plough in 6 rows at the rate of 20 kg/ha in 5 sq m in plots on April 4, 1985. The rows were 33 cm apart and the seed number was kept approximately uniform in each row. There were three replications for each treatment. The four doses of nitrogen, in the form of urea, were given at the time of sowing. A recommended uniform basal dose of 30 kg P and 35 kg K/ha was also broadcast, before sowing in the form of monocalcium superphosphate and muriate of potash respectively (Akhtar, 1985). The field was irrigated thrice between sowing and harvesting. Weeding was done twice during the entire period of crop growth.

The plants were sampled at 20, 30, 40 and 50 DAS, for growth analysis while, various yield parameters and seed yield and quality were studied at harvest (60d).

3.6.2 Experiment 6

This trial was conducted simultaneously with Experiment 5. The physico-chemical properties of the soil are given in Table 1.

The object of the trial was to investigate the phosphatic fertiliser utilisation efficiency of moong (as assessed by its growth, yield and quality performance) taking four doses and studying the effect of their interaction with four levels of pre-sowing seed treatment with pyridoxine.

The experiment was laid out according to factorial randomised block design. The scheme of treatments is given in

Table 7. After soaking, the seeds were inoculated with *Rhizobium* (Section 3.4), and thereafter, sown in the field on April 10, 1985. A uniform basal dose of 10 kg N and 35 kg K/ha was applied to the plots in the form of commercial grade urea and muriate of potash respectively. All the other agricultural practices, including irrigation, weeding, etc., were kept the same as in Experiment 5. Each treatment was replicated thrice.

Sampling was done at 20, 30, 40 and 50d for growth analysis and at harvest (60d) for yield parameters and seed yield and quality.

3.6.3 Experiment 7

This field trial was conducted in the subsequent year, i.e., in the "zaid" season of 1986. The soil characteristics of the field are given in Table 1.

The trial was based on the findings of Experiment 5. The object of the experiment was to investigate the individual and combined effect of foliar spray of nitrogen and pyridoxine soaking along with optimal and sub-optimal basal dose of nitrogen. The foliar application was done at pod filling stage (35d) in the form of aqueous solution of commercial grade urea.

The experiment was conducted according to factorial randomised block design with 10 combinations of treatment as given in Table 8. Each treatment was replicated thrice. The

Table 7. Scheme of treatments for experiment 6 on Summer moong (Factorial randomised)

Sl. No.	Combinations Basal B) x Soaking (S)	Basal treatments	kg N/ha	Soaking treatments	% pyridoxine solution
1.	B_{P15} x S_W	B_{P15}	15	S_W	0.0
2.	B_{P15} x S_1	B_{P15}	15	S_1	0.2
3.	B_{P15} x S_2	B_{P15}	15	S_2	0.3
4.	B_{P15} x S_3	B_{P15}	15	S_3	0.4
5.	B_{P30} x S_W	B_{P30}	30	S_W	0.0
6.	B_{P30} x S_1	B_{P30}	30	S_1	0.2
7.	B_{P30} x S_2	B_{P30}	30	S_2	0.3
8.	B_{P30} x S_3	B_{P30}	30	S_3	0.4
9.	B_{P45} x S_W	B_{P45}	45	S_W	0.0
10.	B_{P45} x S_1	B_{P45}	45	S_1	0.2
11.	B_{P45} x S_2	B_{P45}	45	S_2	0.3
12.	B_{P45} x S_3	B_{P45}	45	S_3	0.4
13.	B_{P60} x S_W	B_{P60}	60	S_W	0.0
14.	B_{P60} x S_1	B_{P60}	60	S_1	0.2
15.	B_{P60} x S_2	B_{P60}	60	S_2	0.3
16.	B_{P60} x S_3	B_{P60}	60	S_3	0.4

N.B.(1) Seeds were soaked for 4h and then treated with rhizobium inoculum

(2) A uniform basal dose of 10 kg N and 35 kg K/ha was applied

Table 8. Scheme of treatments for experiment 7 on Summer moong (Factorial randomised)

Sl. No.	Combinations Basal (B) + Foliar (F) x Soaking (S)	Basal treatments kg N/ha	Foliar treatments kg N/ha	Soaking treatments	% pyridoxine solution
1.	$(B_{N2.5} + F_W) \times S_1$	$B_{N2.5}$ = 2.5 kg N/ha	F_W = (deionised water spray)	S_1	0.2
2.	$(B_{N2.5} + F_W) \times S_2$	$B_{N2.5}$ = 2.5 kg N/ha	F_W = ''	S_2	0.3
3.	$(B_{N5} + F_W) \times S_1$	$B_{N\ 5}$ = 5 kg N/ha	F_W = ''	S_1	0.2
4.	$(B_{N5} + F_W) \times S_2$	$B_N\ 5$ = 5 kg N/ha	F_W = ''	S_2	0.3
5.	$(B_{N2.5} + F_{N1.25}) \times S_1$	$B_{N2.5}$ = 5 kg N/ha	$F_{N1.25}$ = (1.25kg N/ha spray)	S_1	0.2
6.	$(B_{N2.5} + F_{N1.25}) \times S_2$	$B_{N2.5}$ = 5 kg N/ha	$F_{N1.25}$ = ''	S_2	0.3
7.	$(B_{N2.5} + F_{N2.50}) \times S_1$	$B_{N2.5}$ = 5 kg N/ha	$F_{N2.50}$ = (2.5 kg N/ha spray)	S_1	0.2
8.	$(B_{N2.5} + F_{N2.50}) \times S_2$	$B_{N2.5}$ = 5 kg N/ha	$F_{N2.50}$ = ''	S_2	0.3
9.	$(B_{N2.5} + F_{N5}) \times S_1$	$B_{N2.5}$ = 5 kg N/ha	F_{N5} = (5kg N/ha spray)	S_1	0.2
10.	$(B_{N2.5} + F_{N5}) \times S_2$	$B_{N2.5}$ = 5 kg N/ha	F_{N5} = ''	S_2	0.3

N.B.(1) Seeds were soaked for 4h and then treated with rhizobium inoculum

(2) A uniform basal dose of 15 kg P and 35 kg K/ha was applied

(3) Foliar treatments were given at 35d

seeds were soaked for 4h in aqueous pyridoxine solution and later inoculated with rhizobium (Section 3.4). Prior to sowing a uniform basal dose 15 kg P and 35 kg K/ha were applied to the plots. Other agricultural practices including irrigation, weeding, etc., were kept same as in Experiment 5.

Three plants from each plot were collected randomly at 40 and 50d assess their growth performance while yield characteristics and quality of seeds were studied at harvest (60d).

3.6.4 Experiment 8

This factorial randomised field trial was conducted simultaneously with Experiment 7, i.e., in the "zaid" season of 1986. The soil characteristics of the field are given in Table 1.

The trial was based on the findings of Experiment 6. The object of the trial was to investigate the individual and combined effect of foliar spray of phosphorus and pyridoxine soaking together with optimal and sub-optimal basal doses of phosphorus. The foliar application was done at pod filling stage (35d) in the form of aqueous solution of monocalcium superphosphate.

The experiment, conducted according to factorial randomised block design, included 12 combinations of treatment as given in Table 9. Each treatment was replicated thrice. The seeds were soaked for 4h in aqueous pyridoxine solution and later

Table 9. Scheme of treatments for experiment 8 on Summer moong (Factorial randomised)

Sl. No.	Combinations Basal (B) + Foliar (F) x Soaking (S)	Basal treatments kg P/ha	Foliar treatments kg P/ha	Soaking treatments	% pyridoxine solution
1.	$(B_{P10} + F_W) \times S_1$	B_{P10} = 10kg P/ha	F_W = (deionised water spray)	S_1	0.2
2.	$(B_{P10} + F_W) \times S_2$	B_{P10} = 10kg P/ha	F_W = "	S_2	0.3
3.	$(B_{P15} + F_W) \times S_1$	B_{P15} = 15kg P/ha	F_W = "	S_1	0.2
4.	$(B_{P15} + F_W) \times S_2$	B_{P15} = 15kg P/ha	F_W = "	S_2	0.3
5.	$(B_{P10} + F_{P1}) \times S_1$	B_{P10} = 10kg P/ha	F_{P1} = (1kg P/ha spray)	S_1	0.2
6.	$(B_{P10} + F_{P1}) \times S_2$	B_{P10} = 10kg P/ha	F_{P1} = "	S_2	0.3
7.	$(B_{P15} + F_{P1}) \times S_1$	B_{P15} = 15kg P/ha	F_{P1} = "	S_1	0.2
8.	$(B_{P15} + F_{P1}) \times S_2$	B_{P15} = 15kg P/ha	F_{P1} = "	S_2	0.3
9.	$(B_{P10} + F_{P2}) \times S_1$	B_{P10} = 10kg P/ha	F_{P2} = (2kg P/ha spray)	S_1	0.2
10.	$(B_{P10} + F_{P2}) \times S_2$	B_{P10} = 10kg P/ha	F_{P2} = "	S_2	0.3
11.	$(B_{P15} + F_{P2}) \times S_1$	B_{P15} = 15kg P/ha	F_{P2} = "	S_1	0.2
12.	$(B_{P15} + F_{P2}) \times S_2$	B_{P15} = 15kg P/ha	F_{P2} = "	S_2	0.3

N.B.(1) Seeds were soaked for 4h and then treated with rhizobium inoculum

(2) A uniform basal dose of 5kg N and 35kg K/ha was applied

(3) Foliar treatments were given at 35d

inoculated with Rhizobium (Section 3.4). Prior to sowing, a uniform basal dose of 5 kg N and 35 kg K/ha was applied to each plot. Other agricultural practices, including irrigation, weeding etc., were kept similar to those in earlier experiments on moong.

At 40 and 50d, three plants were sampled randomly for assessing their growth performance, while yield characteristics and quality of the seeds were studied at harvest (60d).

3.7 Sampling techniques

Random samples, comprising three plants from each plot at various stages of growth, were collected. To count the number of nodules, the plants were dug out with their roots carefully and washed to wipe away all adhering foreign particles. The following parameters were studied for assessing the growth performance of the crops. The following parameters were studied at the stages specified in each experiment to assess the growth performance of the two crops.

3.7.1 Growth parameters

(a) Root length/plant

(b) Root nodule number/plant

(c) Fresh weight of root/plant

(d) Dry weight of root/plant

(e) Leaf number/plant

3.7.2 Net assimilation rate (NAR)

NAR was calculated according to Milthorpe and Moorby (1979).

$$\text{NAR} = \frac{(W2-W1)}{(t2-t1)} \times \frac{(\text{In } L2-\text{In } L1)}{(L2-L1)}.$$

$$\text{i.e., NAR} = \frac{(W2-W1)}{(t2-t1)} \times \frac{2.303\ (\log 10\ L2-\log 10\ L1)}{(L2-L1)}$$

here;

W1 = dry weight of whole plant at I growth stage

L1 = leaf area of whole plant at I growth stage

t1 = days to sampling at I growth stage

W2 = dry weight of whole plant at II growth stage

L2 = leaf area of whole plant at II growth stage

t2 = days to sampling at II growth stage

In = logarithm to base e

log10 = logarithm to base 10

3.7.3 Yield parameters

The following parameters were studied for yield assessment at the time of harvest, taking random samples of three mature plants for a-c and total thrashed seed harvest for d and e.

(a) Pod number/plant

(b) Pod length

(c) Seed number/pod

(d) 1,000 seed weight

(e) Seed yield

3.8 Chemical analysis

(i) Pyridoxine content of seeds of both the crops was estimated on dry weight basis before sowing them in the field.

(ii) Nitrate reductase activity (NRA) in leaves was measured at various stages of growth on fresh weight basis.

(iii) Nitrogen, phosphorus and potassium content of leaves was estimated at various stages of growth on dry weight basis.

(iv) Protein content of seeds was estimated at harvest for assessing seed quality.

3.8.1 Estimation of pyridoxine

Seeds were dried and powdered. The powder was sieved and pyridoxine content was estimated colorimetrically according to the method of Hochberg *et al*. (1944a,b) which is described below:

3.8.1.1 Preparation of seed extract

Weighed seed powder (1g) was taken in a 20 ml calibrated test tube. To this, 10 ml of 4N hydrochloric acid was added. The test tube was placed in a water-bath and heated for 1h. The contents of the tube was stirred occasionally which helped in hydrolysing the bound pyridoxine as well as in its extraction. The solution was cooled and the pH was adjusted to 3.0 with 1N sodium hydroxide and 1N hydrochloric acid. At this pH, 3 ml of buffer (sodium citrate) was mixed followed by the addition of 2.5g of Fuller's earth (formerly called Llyod's reagent). The tube was stoppered and shaken occasionally for 5 min. The suspension was centrifuged and the supernatant discarded. The residue was washed with 15 ml of acidulated water. 5 ml of 2N sodium hydroxide solution was added to the residue and the final valume was made upto 20 ml with distilled water. The suspension was dispersed for 3 min by frequent inversions of the tube which was thereafter centrifuged. With 10 ml of the elute was mixed 50 ml of isopropanol and it was again centrifuged. The clear supernatant was decanted and its pH adjusted to 5.0 - 7.0 by using a few drops of 12N hydrochloric acid. This extract was used for pyridoxine estimation.

3.8.1.2 Colour development and pyridoxine estimation

The following tubes were set up in order to estimate the pyridoxine content in the seeds:

Test tube 1 : 6 ml test extract + 2 ml ammonia-ammonium chloride solution + 1 ml boric acid solution.

Test tube 2 : 6 ml test extract + 2 ml ammonia-ammonium chloride solution + 1 ml distilled water.

Test tube 3 : 6 ml test extract + 2 ml ammonia-ammonium chloride solution + 1 ml of standard pyridoxine hydrochloride solution containing 10 μg of the vitamin.

In each test tube, 1 ml of 2, 6 dichloroquinone chloroimide solution was added. Test tube 1 acted as the blank. The optical density was read at 660 nm on " Spectronic-20" colorimeter exactly after 1 min of addition of 2, 6 dichloroquinone chloroimide reagent. The pyridoxine content of seeds was calculated by using the following formula :

$$\frac{L_2}{L_3-L_2} \times \frac{10}{6} \times \frac{60}{10} \times \frac{18.5}{W} = \mu g \text{ pyridoxine/g seed powder.}$$

In the above equation :

L_2 represents optical density of the solution present in test tube 2.

L_3-L_2 represents increase in optical density due to the 10 μg pyridoxine added in test tube 3.

W stands for weight of seed powder used.

$\frac{60 \times 18.5}{10}$ is used for dilution factor.

3.8.2.1 Estimation of NRA

NRA was estimated in fresh leaf pieces. Random samples of leaves from each plot were taken and cut into small pieces. The enzyme activity was determined according to the method of Jaworski (1971) described briefly below :

500 mg leaf pieces were weighed and placed in polythene vials. To each, 2.5 ml of phosphate buffer pH 7.0 and 0.5 ml of 0.2M potassium nitrate solution were added, followed by addition of 2.5 ml of 5% isopropanol. Lastly, two drops of chloromphenicol solution were added to avoid bacterial growth in the medium. These vials were incubated for 2h in dark at 30°C.

3.8.2.2 Colour development

0.4 ml of incubated mixture was taken in a test tube to which 0.3 ml of 1% sulphanilamide and 0.02% N-1 - nephthyl ethylene diamine hydrochloride (NED-HCl) were added. The solution was left for 20 min for maximum colour development.

It was diluted to 5 ml with sufficient amount of distilled water and optical density was read at 540 nm using a " Spectronic-20" colorimeter. A blank consisting of 4.4 ml of distilled water plus 0.3 ml each of sulphanilamide and NED-HCl was used simultaneously for comparison.

A standard curve was plotted by taking known, graded dilutions of potassium nitrite from a standard aqueous solution of this salt. The optical density of the samples was compared with this calibrated curve and NRA was expressed as n mol NO_2^-/g/h fresh leaf tissue.

3.8.3 Estimation of leaf NPK

Three plants from each plot were randomly chosen, cleaned with dry cloth and dried in an oven for 24h. Healthy leaves were plucked, powdered and passed through a 72 mesh screen. Nitrogen, phosphorus and potassium were estimated as described below :

3.8.3.1 Digestion of leaf powder

Leaf powder was digested according to Lindner (1944) for the estimation of nitrogen, phosphorus and potassium content of the leaf. To start with, 100 mg of dry leaf powder was taken in a 50 ml Kjeldhal flask. To this, 2 ml of conc. sulphuric acid was added and the mixture heated for 2h which turned the contents black. After cooling for 15 min, 0.5 ml of chemically pure 30% hydrogen peroxide was added drop by drop. The solution was again heated for about 30 min till the colour became light yellow. It was then cooled and 3-4 drops of hydrogen peroxide were added and again heated for about 15 min to get a clear solution. Excess of hydrogen peroxide was avoided as it could oxidise ammonia in the absence of organic matter. The peroxide digested material was transferred to a 100 ml volumetric flask with three or four washings with distilled water and the volume was made upto the mark.

3.8.3.2 Estimation of nitrogen

The method of Lindner (1944) was adopted for the estimation of nitrogen in the samples.

A 10 ml aliquot of the peroxide digested material was taken in a 50 ml volumetric flask. To it, 2 ml of 2.5 N sodium hydroxide and 1 ml of 10% sodium silicate solutions were added to neutralise excess of acid and to prevent turbidity respectively. The volume of the solution was made upto the mark with the help of distilled water. In a 10 ml graduated test tube, 5 ml aliquot of this solution was taken and 0.5 ml Nessler's reagent was added mixing thoroughly by vigorous stirring. The final volume (10 ml) was made up with distilled water. After waiting for 5 min to get optimum colour development, the optical density of the solution was determined at 525 nm with a " Spectronic-20" colorimeter. A blank, consisting of distilled water and Nessler's reagent, was run simultaneously. A standard curve, taking known dilutions of a standard ammonium sulphate solution, was plotted. The reading of each sample was compared with this calibration curve and nitrogen in leaves was estimated in terms of percentage on dry weight basis.

3.8.3.3 Estimation of phosphorus

Total phosphorus in the sulphuric acid-peroxide digest was estimated by the method of Fiske and Subba Row (1925). A 5 ml aliquot was taken in a 10 ml graduated test tube and 1 ml of molybdic acid (2.5% ammonium molybdate in 10N sulphuric acid) was added carefully followed by the addition of 0.4 ml of 1-amino-2-naphthol-4-sulphonic acid. The colour turned blue. Distilled water was used to make up the volume to 10 ml. The solution was shaken, kept for 5 min and then transferred to a colorimetric tube. The optical density was read at 620 nm on a " Spectronic-20" colorimeter. A blank was run simultaneously with each determination. A standard curve was prepared by using known concentrations of monobasic potassium phosphate solution. The reading of samples was compared with this curve and phosphorus content in leaves was computed in terms of percentage on dry weight basis.

3.8.3.4 Estimation of potassium

Potassium content was estimated flame photometrically. A 10 ml aliquot was taken and it was read by using the filter for potassium. A blank was run side by side. The readings were compared with a calibration curve plotted with the help of known dilutions of a standard potassium sulphate solution. The potassium in leaves was expressed as per cent on a dry weight basis.

3.8.4 Estimation of seed protein

The protein content of seeds was extracted according to Yih and Clark (1965) and estimated by the method of Lowry *et al.* (1951). Sufficient amount of seed powder was spread over a sheet of paper and dried overnight in an oven at 80^{o}C. The dried samples were cooled in a dessicator for about 5 min before weighing. 50 mg of each sample was taken and transferred to a mortar. To it was added 1 ml of cold 5% trichloroacetic acid.

The powder was ground well and the homogenate was collected in a centrifuge tube with repeated washings with trichloroacetic acid. The volume was made upto 5 ml with 5% trichloroacetic acid. It was kept for 1h to allow the complete precipitation of proteins. The samples were then centrifuged at 4,000 rpm for 15 min and the supernatant was discarded. To the residue, 5 ml of 1N sodium hydroxide solution was added and shaken well for complete mixing. It was kept for half an hour on a water bath at 60°C so as to dissolve the precipitated proteins completely. After cooling for 15 min, the mixture was centrifuged at 4,000 rpm for 15 min and the supernatant containing the protein was collected. It was then diluted with appropriate quantity of water and used for estimation of total protein in the seed.

3.8.4.1 Colour development

1 ml of the diluted aliquot was taken in a test tube. To it, 5 ml of reagent B was added and left for 10 min. Afterward, 0.5 ml of Folin's reagent was added with immediate mixing and kept for half an hour for optimum colour development. The optical density of each sample was measured at 660 nm on a "Spectronic-20" colorimeter. A blank, containing distilled water, reagent B and Folin's reagent, was used simultaneously with each sample. The reading was compared with a calibration curve obtained by using known dilution of standard egg albumen solution.

The reagents used in all chemical analyses described above (Section 3.8) were prepared as described in the Appendix.

3.9 Statistical analysis

All data were analysed statistically taking into consideration the variables in each experiment according to Panse and Sukhatme (1985).

The "F" test was applied to assess the significance of the data at 5% level of probability ($P \leq 0.05$). The error due to replicates was also determined. The models of the analysis of variance (ANOVA) are given in Table 10. Critical difference (C.D.) was calculated to compare the effect of various treatments, using the following formulae:

(i) C.D. at 5% for factor I $= \sqrt{\frac{2 \times \text{Error (MSS)}}{3 \times \text{factor II}}} \times t_{5\%}$

(ii) C.D. at 5% for factor II $= \sqrt{\frac{2 \times \text{Error (MSS)}}{3 \times \text{factor I}}} \times t_{5\%}$

(iii) C.D. at 5% for interaction $= \sqrt{\frac{2 \times \text{Error (MSS)}}{3}} \times t_{5\%}$

Table 10. Models of analysis of variance (ANOVA)

Experiment 1 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal N, treatments (B)	3			
Soaking treatments (S)	3			
Interactions (BxS)	9			
Error	30			
Total	47			

Experiment 2 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal P, treatments (B)	3			
Soaking treatments (S)	3			
Interactions(BxS)	9			
Error	30			
Total	47			

Experiment 3 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal + Foliar N, treatments (B+F)	5			
Soaking treatments (S)	1			
Interactions(B+F) x S	5			
Error	22			
Total	35			

Table 10 (contd.) Model of analysis of variance (ANOVA)

Experiment 4 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal+Foliar P, treatments (B+F)	5			
Soaking treatments (S)	1			
Interactions (B+F)xS	5			
Error	22			
Total	35			

Experiment 5 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal N, treatments (B)	3			
Soaking treatments (S)	3			
Interactions (BxS)	9			
Error	30			
Total	47			

Experiment 6 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal P, treatments (B)	3			
Soaking treatments (S)	3			
Interactions (BxS)	9			
Error	30			
Total	47			

Table 10. (contd.) Model of analysis of variance (ANOVA)

Experiment 7 (Fractorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal+Foliar N, treatments (B+F)	4			
Soaking treatments (S)	1			
Interactions(B+F)xS	4			
Error	18			
Total	29			

Experiment 8 (Fractorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	F
Replications	2			
Basal+Foliar P, treatments(B+F)	5			
Soaking treatments (S)	1			
Interactions(B+F)xS	5			
Error	22			
Total	35			

N.B.

D.F. Degree of freedom

S.S. Sum of squares

M.S.S. Mean square

F Variance ratio

CHAPTER 4

EXPERIMENTAL RESULTS

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EXPERIMENTAL RESULTS

4.1 Experiment 1

In this factorial randomised field trial on lentil var. T-36, the effects of four basal doses of nitrogen, i.e., 15 kg N/ha (B_{N15}), 30 kg N/ha (B_{N30}), 45 kg N/ha (B_{N45}) and 60 kg N/ha (B_{N60}) and pre-sowing seed treatment with graded squeous pyridoxine solution, viz., water-soaked (S_W), 0.2%(S_1) 0.3% (S_2), and 0.4% (S_3), alone and in combination, were studied on growth characteristics, net assimilation rate (NAR), leaf nitrate reductase activity (NRA), leaf NPK content , yield attributes, seed yield and seed protein content. The data are summarised in Table 11-16 and briefly described below :

4.1.1 Growth characteristics

Five growth parameters, namely, root length, root nodule number, root fresh weight, root dry weight and leaf number were studied at 60, 90 and 120 days (d) after sowing (Tables 11-13).

4.1.1.1 Root length per plant

The effect of nitrogen application and of pre-sowing seed treatment with vit. B_6 separately and of their interaction on root growth found significant at all growth stages (Table 11).

Table 11. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on root length and root nodule number per plant of lentil var. T-36 (Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatment (% pyridoxine)														
	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean
Root length (cm)															
B_{N15}	6.33	5.66	6.66	4.33	5.75	5.33	6.33	7.00	6.66	6.33	7.00	7.35	8.33	8.00	7.67
B_{N30}	5.66	7.66	8.66	5.33	6.83	6.17	7.00	8.16	6.00	6.83	7.34	8.33	8.66	7.00	7.83
B_{N45}	5.66	8.33	9.00	4.66	6.91	6.50	7.33	8.33	5.66	6.96	7.44	8.36	8.66	7.00	7.87
B_{N60}	5.33	5.66	6.33	4.00	5.33	6.00	6.66	7.00	5.00	6.17	7.00	7.00	8.00	6.88	7.22
Mean	5.75	6.83	7.66	4.58		6.00	6.83	7.62	5.83		7.20	7.76	8.41	7.22	
C.D. at 5%	B=0.29, S=0.29, BxS=0.57					B=0.37, S=0.37, BxS=0.73					B=0.13, S=0.13, BxS=0.26				
Root nodule number															
B_{N15}	9.00	7.00	13.00	9.66	9.67	9.34	8.33	13.66	11.00	10.58	2.36	2.00	3.23	2.66	2.56
B_{N30}	8.00	13.33	15.00	7.33	10.92	8.00	17.66	20.00	7.66	13.33	2.00	2.33	3.66	3.42	2.85
B_{N45}	9.00	14.00	17.66	7.33	12.00	9.33	20.00	20.66	7.33	14.33	1.66	3.33	3.05	2.56	2.65
B_{N60}	7.33	9.33	10.66	6.67	8.50	7.33	9.66	11.66	7.00	8.91	2.00	2.00	2.43	2.45	2.22
Mean	8.33	10.92	14.08	7.75		8.50	13.91	16.50	8.25		2.01	2.42	3.09	2.77	
C.D. at 5%	B=1.53, S=1.53, BxS=3.06					B=1.31, S=1.31, BxS=2.62					B=N.S., S=0.65, BxS=N.S.				

N.S. = Non-significant

On comparing the effect of nitrogen, it was noted that nitrogen application upto B_{N45} increased root length gradually and the highest dose, i.e., B_{N60} proved deliterious at all growth stages. Application of B_{N30} proved optimum. It was, however, at par with B_{N45} in its effect at all stages.

Regarding soaking treatments, S_2 gave maximum value at all growth stages. At 60 days, S_3 had minimum value while at later stages, the lowest value was given by water soaked control (S_W), but the valueswere at par with that for S_3.

Considering the interaction effect $B_{N30} \times S_2$ equalled by $B_{N45} \times S_2$, produced longest roots at all three stages. However, at 60d the effect of $B_{N30} \times S_2$ was at par with that of $B_{N45} \times S_1$. $B_{N15} \times S_W$ (control) generally gave poor response at all growth stages, with $B_{N60} \times S_3$ giving the poorest results. The combined dose ($B_{N30} \times S_2$) showed an increase of 36.81% at 60d, 53.10% at 90d and 23.71% at 120d over $B_{N15} \times S_W$.

4.1.1.2 <u>Root nodule number per plant</u>

The effect of basal nitrogen and pyridoxine treatment of seeds and of their interaction was significant at 60 and 90d. At 120d, the effect of pre-sowing seed treatment with pyridoxine only found significant (Table 11).

B_{N45} (equalled by B_{N30}) produced maximum number of root nodules at 60 and 90d. B_{N60} and B_{N15}, being equal in their effect, gave lowest value. With respect to soaking treatment S_2 gave maximum value at all growth stages and the values differed critically from those for other treatments, except S_3 at 120d.

Pertaining to the interaction effect of nitrogen and pyridoxine treatment, it was noted that B_{N30} x S_2, equalled by B_{N45} x S_2, gave maximum values at 60 and 90d. However, at 90d, it showed equal effect with B_{N45} x S_1. The treatment B_{N30} x S_2 showed an increase of 66.67 and 114.13% at 60 and 90d respectively over B_{N15} x S_W.

4.1.1.3 Root fresh weight per plant

It is evident from Table 12 that the effect of nitrogen and pyridoxine treatment were significant at 60, 90 and 120d. However, the interaction effect was significant only at 90 and 120d.

Regarding the effect of nitrogen, maximum fresh weight of root was recorded in B_{N30} and the value differed critically with all others at 60 and 90d; whereas, at 120d, it was at par with that for B_{N45}, control (B_{N15}) gave poorest effect.

Pertaining to pyridoxine treatment, maximum fresh weight was recorded in treatment S_2 at 120d. While at 60 and 90d the effect of this treatment was statistically equal to that of S_1, S_W (control) and S_3 showed equal and poorest effect.

Table 12. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on fresh and dry weights of root per plant of lentil var.T-36
(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Fresh weight of root (g)														
B_{N15}	0.066	0.076	0.086	0.053	0.070	0.126	0.130	0.103	0.166	0.131	0.800	0.700	0.800	0.966	0.817
B_{N30}	0.073	0.093	0.116	0.069	0.088	0.113	0.216	0.256	0.133	0.180	0.880	1.000	1.180	0.833	1.128
B_{N45}	0.076	0.100	0.012	0.073	0.065	0.133	0.126	0.250	0.133	0.161	0.900	1.200	1.830	0.830	1.190
B_{N60}	0.068	0.077	0.083	0.055	0.071	0.140	0.233	0.100	0.170	0.161	0.833	0.880	0.866	0.700	0.820
Mean	0.071	0.087	0.074	0.063		0.128	0.176	0.177	0.151		0.853	0.945	1.324	0.832	
C.D. at 5%	B = 0.014, S = 0.014, BxS = N.S.					B = 0.013, S = 0.013, BxS = 0.026					B = 0.067, S = 0.067, BxS = 0.133				
	Dry weight of root (g)														
B_{N15}	0.040	0.060	0.060	0.056	0.054	0.070	0.083	0.093	0.090	0.084	0.080	0.093	0.116	0.103	0.098
B_{N30}	0.053	0.067	0.075	0.050	0.061	0.083	0.103	0.116	0.080	0.096	0.090	0.140	0.153	0.090	0.118
B_{N45}	0.053	0.067	0.077	0.046	0.061	0.086	0.110	0.123	0.070	0.097	0.100	0.150	0.153	0.080	0.121
B_{N60}	0.046	0.056	0.056	0.043	0.050	0.073	0.090	0.093	0.070	0.082	0.083	0.103	0.103	0.076	0.091
Mean	0.048	0.063	0.067	0.049		0.078	0.097	0.106	0.078		0.088	0.122	0.131	0.087	
C.D. at 5%	B = 0.005, S = 0.005, BxS = 0.010					B = 0.006, S = 0.006, BxS = 0.012					B = 0.002, S = 0.002, BxS = 0.004				

N.S.= Non-significant

When interaction effect was taken into consideration, it was noted that B_{N45} x S_2 equalled by B_{N30} x S_2 gave maximum root fresh weight at 90 and 120d. The combined dose of B_{N30} and S_2 increased fresh weight of root by 103.17 and 125.00% at 90 and 120d respectively over B_{N15} x S_W.

4.1.1.4 Root dry weight per plant

The effect of nitrogen and pyridoxine and of their interaction on root dry matter production was significant at all growth stages (Table 12).

The application of nitrogen at the rate of 45 kg N/ha (B_{N45}) resulted in the production of maximum root dry weight at all growth stages, its value differing critically from those given by all other dressings at 120d; but at 60 and 90d it was at par with that for B_{N30}. Control (B_{N15}) and B_{N60} showed poorest and similar effect.

Regarding pyridoxine treatment, it was observed that S_2 produced significantly maximum dry weight at all growth stages, except at 60d, where this treatment was at par with S_1. On the other hand, the control (S_W) and S_3 (being statistically equal) gave lowest values.

Considering the interaction effect of nitrogen application and pyridoxine treatment, B_{N30} x S_2 (equalled by B_{N45} x S_2) proved best at all three stages. However, at 60d, the interactions B_{N30} x S_1 and B_{N45} x S_1 were at par with the above combinations and at 120d the value was also at par with that for B_{N45} x S_1. B_{N30} x S_2 showed an increase in dry weight of 87.5% at 60d, 65.71% at 90d and 91.25% at 120d compared with B_{N15} x S_W.

4.1.1.5 Leaf number per plant

The effect of basal nitrogen, pyridoxine treatment and of their interaction on leaf number was significant at all growth stages (Table 13).

Regarding the effect of nitrogen application, it was noted that B_{N45} (equalled by B_{N30}) proved best and differed critically from the lowest, i.e., B_{N15} (control) and highest basal dose, viz. B_{N60}, which showed the poorest effect at all growth stages.

As far as the effect of pyridoxine treatment was concerned, S_2 proved optimum at all growth stages and the value differed critically from those for all other treatments. S_W (control) and S_3 had poorest effect.

Pertaining to the interaction effect, it was observed that B_{N45} x S_2 produced maximum number of leaves at all three stages. However, at 60d and 90d, it was at par with that for B_{N30} x S_2. B_{N15} x S_W and B_{N60} x S_4 were at par and gave lowest value at the most stages. The increase due to the B_{N30} x S_2 over B_{N15} x S_W (control) at 60, 90 and 120d was 104.43, 61.67 and 66.12% respectively. Moreover, at 120d, the increase due to the B_{N45} x S_2 was 77.83% in comparison with B_{N15} x S_W.

Table 13. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, netassimilation rate (NAR) and nitrate reductase activity (NRA) of lentil var. T-36

(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
								Leaf number							
B_{N15}	30.00	37.00	45.33	40.33	38.17	60.00	73.33	79.66	74.66	17.91	79.66	85.33	108.66	94.66	92.08
B_{N30}	35.66	46.33	61.33	35.33	44.66	72.33	86.66	97.00	68.33	81.08	108.66	114.00	132.33	86.00	110.25
B_{N45}	38.00	46.66	64.00	32.66	45.33	74.00	94.66	102.33	64.66	83.91	93.33	125.66	141.66	85.33	111.50
B_{N60}	33.00	38.66	40.66	29.66	35.50	67.33	74.33	77.33	58.66	69.41	85.33	94.00	98.33	77.33	88.75
Mean	34.17	42.16	52.83	34.50		68.42	82.25	89.08	66.58		91.75	104.75	120.25	85.83	
C.D. at 5%	B = 1.38, S = 1.38, BxS = 2.76					B = 2.84, S = 2.84, BxS = 5.67					B = 3.17, S = 3.17, BxS = 6.33				
								NAR ($x10^{-4}g/cm^2/d$)							
	(60–90d interval)					(90–120d interval)									
B_{N15}	2.53	3.28	4.13	3.64	3.40	1.29	1.67	2.11	1.86	1.73					
B_{N30}	3.20	4.34	5.49	3.19	4.06	1.34	2.12	2.47	1.34	1.82					
B_{N45}	3.33	4.66	5.67	2.54	4.05	1.79	2.13	2.63	1.33	1.97					
B_{N60}	2.76	3.43	3.83	2.53	3.15	1.33	1.83	1.86	1.26	1.57					
Mean	2.96	3.93	4.79	2.98		1.44	1.94	2.27	1.45						
C.D. at 5%	B = 0.43, S = 0.43, BxS = 0.87					B = 0.16, S = 0.16, BxS = 0.32									
								NRA (n mol NO_2^- /g/h)							
B_{N15}	108.66	115.53	123.33	121.39	117.23	86.34	96.46	103.66	103.33	97.45	61.66	71.34	80.42	77.93	72.84
B_{N30}	113.68	126.88	133.66	113.66	121.97	90.36	104.88	113.66	88.96	99.47	67.76	83.33	89.90	67.68	77.17
B_{N45}	120.66	127.86	136.70	108.98	123.55	100.33	106.34	116.36	87.73	102.69	73.33	87.37	90.33	65.53	79.14
B_{N60}	110.75	120.67	121.58	106.90	114.98	87.73	100.52	103.33	85.44	94.26	65.58	74.63	78.66	60.43	69.83
Mean	113.44	122.74	128.82	112.73		91.19	102.05	109.25	91.37		67.08	79.17	84.83	67.89	
C.D. at 5%	B = 4.48, S = 4.48, BxS = 8.96					B = 3.07, S = 3.07, BxS = 6.14					B = 2.27, S = 2.27, BxS = 4.54				

4.1.2 Net assimilation rate (NAR)

NAR was determined for 60-90 and 90-120 days and the effect of nitrogen, pyridoxine and of their interaction was found significant (Table 13).

Regarding the effect of nitrogen, B_{N45} equalled by B_{N30} gave highest NAR at both intervals. On the other hand, B_{N15} (being at par with B_{N60}) showed the poorest effect.

Regarding pyridoxine treatment, S_2 gave maximum value at both intervals, S_W (control), showing equal effect with S_3, gave minimum value.

Among the interactions, B_{N45} x S_2 (equalled by B_{N30} x S_2) gave maximum value for both intervals. Application of B_{N30} x S_2 increased NAR by 117.00 and 91.47% during 60-90 and 90-120d respectively over B_{N15} x S_W.

4.1.3 Nitrate reductase activity (NRA)

Leaf NRA was estimated at 60, 90 and 120d after sowing and the effect of nitrogen application, pyridoxine treatment and their interaction was found to be significant at all stages (Table 13).

Among the various nitrogen treatments, B_{N45} proved optimum at all growth stages. However, the value was at par with that for B_{N30} at 60 and 120d and differed critically with B_{N15} at all growth stages.

As far as pyridoxine treatment was concerned, it was noted that S_2 gave maximum value at 60, 90 and 120d. At all three stages, S_W (being at par with S_3) registered lowest value.

Among various interactions, $B_{N30} \times S_2$, $B_{N45} \times S_2$ and $B_{N45} \times S_1$ at 60 and 120d as also $B_{N30} \times S_2$ and $B_{N45} \times S_2$ at 90d (showing equal effect) gave maximum value of NRA. Compared to $B_{N15} \times S_W$, the treatment $B_{N30} \times S_2$ enhanced NRA by 23.00, 31.64 and 45.80% at 60, 90 and 120d respectively.

4.1.4 Leaf NPK content

Leaf nitrogen, phosphorus and potassium was estimated in fully expanded leaves at 60, 90 and 120d after sowing. The data at all stages are presented in Table 14 and summarised below :

4.1.4.1 Nitrogen

The effect of nitrogen and pyridoxine treatment as well as of their interaction on the concentration of leaf nitrogen was noted to be significant at all growth stages (Table 14).

At all three stages B_{N45} (equalled by B_{N30}) had higher nitrogen content in comparison to other treatments. The lowest value was recorded in B_{N60}. The increase in nitrogen content was gradual from B_{N15} to B_{N45} at all stages.

Table 14. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content (%) of lentil var. T-36
(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
						Nitrogen content									
B_{N15}	4.33	4.86	5.64	5.46	5.07	2.16	3.33	4.57	3.83	3.47	1.33	1.50	3.16	3.06	2.26
B_{N30}	4.76	5.68	6.13	4.48	5.26	3.08	4.68	5.33	2.83	3.98	1.50	3.16	3.33	2.33	2.58
B_{N45}	5.03	5.75	6.33	4.33	5.36	3.33	4.77	5.66	2.33	4.02	2.34	3.24	3.63	1.37	2.65
B_{N60}	4.37	5.16	5.47	4.30	4.83	2.46	3.66	4.55	2.08	3.19	1.46	2.53	3.13	1.27	2.10
Mean	4.62	5.36	5.89	4.64		2.76	4.11	5.03	2.77		1.66	2.61	3.31	2.01	
C.D. at 5%	B = 0.16, S = 0.16, BxS = 0.32					B = 0.22, S = 0.22, BxS = 0.43					B = 0.084, S = 0.084, BxS = 0.168				
						Phosphorus content									
B_{N15}	0.297	0.430	0.500	0.480	0.427	0.152	0.266	0.343	0.322	0.271	0.132	0.150	0.200	0.170	0.163
B_{N30}	0.407	0.500	0.633	0.394	0.484	0.233	0.366	0.466	0.233	0.325	0.136	0.233	0.260	0.136	0.191
B_{N45}	0.466	0.504	0.663	0.333	0.492	0.300	0.367	0.483	0.156	0.327	0.152	0.233	0.266	0.133	0.196
B_{N60}	0.333	0.466	0.483	0.296	0.394	0.206	0.306	0.340	0.151	0.251	0.133	0.170	0.173	0.130	0.152
Mean	0.376	0.475	0.570	0.376		0.223	0.326	0.408	0.216		0.138	0.197	0.225	0.142	
C.D. at 5%	B = 0.062, S = 0.062, BxS = 0.124					B = 0.037, S = 0.037, BxS = 0.074					B = 0.017, S = 0.017, BxS = 0.034				
						Potassium content									
B_{N15}	3.28	4.10	4.86	4.66	4.23	2.33	3.65	4.30	3.86	3.54	1.26	1.66	2.33	2.00	1.81
B_{N30}	3.86	5.22	5.33	3.74	4.54	2.97	4.33	4.66	2.67	3.66	1.36	2.33	2.66	1.33	1.92
B_{N45}	4.30	5.30	5.63	3.33	4.64	3.66	4.38	4.86	2.33	3.81	1.84	2.46	2.76	1.32	2.10
B_{N60}	3.66	4.33	4.66	3.26	3.98	2.45	3.66	4.30	2.28	3.17	1.33	2.00	2.06	1.22	1.65
Mean	3.78	4.74	5.12	3.75		2.85	4.01	4.53	2.79		1.45	2.11	2.45	1.47	
C.D. at 5%	B = 0.16, S = 0.16, BxS = 0.32					B = 0.17, S = 0.17, BxS = 0.35					B = 0.13, S = 0.13, BxS = 0.26				

Regarding pyridoxine treatment, it was noted that S_2 gave maximum values for leaf nitrogen content at all stages. S_W (control) gave lowest value for leaf nitrogen content at all growth stages but the value was at par with that for S_3 at 60 and 90 days.

Among the various combinations of nitrogen and pyridoxine treatment, $B_{N30} \times S_2$ proved optimum at all growth stages. However, at 60 and 90d, the value was at par with that for $B_{N45} \times S_2$. The increase due to $B_{N30} \times S_2$ at 60 and 90d was 41.57 and 146.76% respectively; while, at 120d the increase due to $B_{N30} \times S_2$ and $B_{N45} \times S_2$ was 150.38 and 172.93% respectively in comparison with $B_{N15} \times S_W$.

4.1.4.2 Phosphorus

It is evident from the Table 14 that the effect of nitrogen and pyridoxine treatment alone as well as of their interaction on the phosphorus content of leaves was significant at all three stages.

Considering the effect of nitrogen application, phosphorus content in the leaves was maximum in the treatment B_{N30} and the value differed critically from those for all other treatments except B_{N45} at all stages. Application of B_{N15} and B_{N60} (being at par in their effect) gave poorest value.

Taking the effect of pyridoxine soaking into consideration, it was noted that S_2 gave maximum value for leaf phosphorus content at all stages.

With regard to the interaction effect, it was noted that $B_{N30} \times S_2$ proved optimum at all stages, but the value was statistically equal to that for $B_{N45} \times S_2$ at 60 and 90d and at 120d, to those for $B_{N30} \times S_1$, $B_{N45} \times S_1$ and $B_{N45} \times S_2$. On the other hand, $B_{N15} \times S_W$ (being at par with $B_{N60} \times S_3$ and some other interactions) gave lowest value at all growth stages. The treatment $B_{N30} \times S_2$ increased leaf phosphorus content by 113.13% at 60d, 206.58% at 90d and 96.97% at 120d over $B_{N15} \times S_W$.

4.1.4.3 Potassium

Potassium content of the leaves was also significantly affected by nitrogen and pyridoxine treatment and by their interaction at all growth stages (Table 14).

The maximum potassium content was recorded in the B_{N45} at all growth stages. However, at 60 and 90d the effect of this treatment was at par with that of B_{N30}. The control (B_{N15}) gave significantly lowest value.

With regard to the effect of pyridoxine treatment on the potassium content of leaves, it was found that S_2 gave the maximum values at all stages. On the other hand, S_W (control) and S_3 (being at par) gave the lowest value.

Taking interaction effect into consideration, $B_{N45} \times S_2$ (being at par with $B_{N30} \times S_2$) gave the maximum value at all stages. The interaction $B_{N15} \times S_W$ (control) (being at par with $B_{N60} \times S_3$) gave the lowest value. The treatment $B_{N30} \times S_2$ enhanced leaf potassium content by 62.5% at 60d, 100% at 90d and 111.11% at 120d in comparison with $B_{N15} \times S_W$.

4.1.5 Yield characteristics

Five yield parameters (pod number per plant, pod length, seed number per pod, 1,000 seed weight, seed yield) were studied at harvest. The effect of nitrogen dressing, pyridoxine treatment and of their interactions was found significant for pod number/plant and seed yield. Moreover, nitrogen and pyridoxine treatment alone affected 1,000 seed weight. The two remaining yield attributes, viz.,pod length and number of seed per pod remained unaffected (Tables 15-16).

4.1.5.1 Pod number per plant

A gradual increase in pod number was found from B_{N15} to B_{N45}. The lowest value was given by B_{N60}. The effect of various nitrogen levels differed critically from each other. Of various pyridoxine treatments, S_2 proved best and the value differed critically from those for all other treatments. S_W (control) produced the lowest number of pods and the value was statistically equal to that for S_3.

Among various interactions, B_{N30} x S_2 (equalled by the B_{N45} x S_2) produced maximum number of pods per plant and this value differed critically from those for all other interactions. The interaction B_{N30} x S_2 produced 119.78% more pods per plant than B_{N15} x S_W (Table 15).

4.1.5.2 Pod length

As mentioned earlier, nitrogen and pyridoxine treatments separately as well as through their interaction had the same effect on length per pod as their respective controls (Table 15).

4.1.5.3 Seed number per pod

This parameter was also not affected significantly, like pod length (Section 4.1.5.2) by any of the treatments on their interaction (Table 15).

4.1.5.4 1,000 seed weight

The individual effect of nitrogen and pyridoxine treatments was significant for 1,000 seed weight, but interaction effect was non-significant (Table 16). Among various nitrogen levels, B_{N30} produced heaviest seeds but its effect was statistically equal to that of B_{N45}. The lowest value was recorded in B_{N60} (at par with B_{N15}).

Regarding the response of pyridoxine treatment, the effect of S_2 and S_W registered significant maximum and minimum values respectively.

Table 15. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of lentil var. T-36

(Mean of three replicates)

Soaking treatments (% pyridoxine)

Pod number/plant

Basal treatments (kg N/ha)	S_w	S_1	S_2	S_3	Mean
B_{N15}	87.66	106.66	122.33	121.33	109.50
B_{N30}	103.66	131.66	192.66	100.33	132.08
B_{N45}	109.66	177.00	194.37	89.46	142.62
B_{N60}	91.00	118.00	121.33	85.34	103.92
Mean	98.00	133.33	157.67	99.12	
C.D. at 5%	B = 5.34, S = 5.34, BxS = 10.67				

Pod length (cm)

Basal treatments (kg N/ha)	S_w	S_1	S_2	S_3	Mean
B_{N15}	0.866	0.846	0.942	0.786	0.850
B_{N30}	0.833	0.983	0.980	0.968	0.941
B_{N45}	0.786	0.984	0.986	0.933	0.923
B_{N60}	0.854	0.896	0.796	0.733	0.820
Mean	0.835	0.927	0.926	0.855	
C.D. at 5%	B = N.S., S = N.S., BxS = N.S.				

Seed number/pod

Basal treatments (kg N/ha)	S_w	S_1	S_2	S_3	Mean
B_{N15}	1.82	1.75	1.84	1.83	1.81
B_{N30}	1.81	1.88	1.93	1.83	1.86
B_{N45}	1.82	1.90	1.96	1.88	1.89
B_{N60}	1.83	1.83	1.83	1.83	1.83
Mean	1.82	1.84	1.89	1.84	
C.D. at 5%	B = N.S., S = N.S., BxS = N.S.				

N.S. = Non-significant

Table 16. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of lentil var.T-36

(Mean of three replicates)

Basal treatments (kg N/ha)	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	1,000 seed weight (g)					Seed yield (q/ha)					Protein content (%)				
B_{N15}	20.33	20.66	21.58	21.30	20.97	11.67	14.83	16.83	15.83	14.79	20.47	20.58	21.66	21.30	21.00
B_{N30}	20.48	21.65	21.66	20.48	21.07	13.33	17.80	19.98	13.33	16.11	20.53	22.45	23.42	20.50	21.73
B_{N45}	20.94	21.65	21.73	20.33	21.16	15.66	17.89	20.30	11.66	16.38	20.66	21.96	23.06	20.50	21.55
B_{N60}	20.38	20.96	21.33	20.30	20.74	12.70	15.40	18.86	11.63	14.65	20.50	21.08	21.33	20.43	20.84
Mean	20.53	21.23	21.58	20.61		13.34	16.48	18.99	13.11		20.54	21.52	22.37	20.68	
C.D. at 5%	B = 0.14, S = 0.14, BxS = N.S.					B = 0.23, S = 0.23, BxS = 0.46					B = 0.40, S = 0.40, BxS = 0.79				

N.S. = Non-significant

4.1.5.5 Seed yield

As mentioned earlier, the effect of nitrogen application, pyridoxine treatment as well as their interaction was significant on the economic (seed) yield of lentil (Table 16).

Among various nitrogen treatments, B_{N45} gave significant maximum yield. The value given by this treatment was critically different from those for the remaining treatments. On the other hand, B_{N15} and B_{N60} (being equal) gave lowest yield.

Pertaining to pyridoxine treatment, S_2 gave maximum seed yield that differed statistically from those in the other treatments. On the other hand, S_W and S_3 were equal in their effect and gave lowest value.

Regarding the interaction effect, it was observed that $B_{N30} \times S_2$ gave highest seed yield which was at par with that for $B_{N45} \times S_2$. The value of these interactions differed significantly from those for all other interactions. An increase 71.21% due to the $B_{N30} \times S_2$ over $B_{N15} \times S_W$ was noted.

4.1.6 Seed protein content

Seed protein content was (equally) enhanced most by B_{N30} and B_{N45}. Their effect differed critically from that of the rest of the treatments.

With regard to the effect of pyridoxine treatment on the protein content of seeds, it was found that S_2 registered maximum protein content. Treatment S_W (control) gave the lowest value which differed critically from those for other treatments, except S_3.

Regarding the interaction effect, it emerged that $B_{N30} \times S_2$ gave the highest protein content; but the value was at par with that for $B_{N45} \times S_2$ only (Table 16). An increase of 12.65% was recorded in the $B_{N30} \times S_2$ over $B_{N15} \times S_W$.

Considering the entire data of this experiment, it may be concluded that treating the seeds of lentil with a 0.3 per cent aqueous pyridoxine solution for 12h and applying 30 kg N (with 45 kg P and 30 kg K /ha) at the time of sowing ensured optimum seed yield and quality of this crop. Therefore, these treatments may be adopted by the farmers of this region (Western Uttar Pradesh) for profitable cultivation of lentil.

4.2 Experiment 2

In this factorial randomised field trial, the effects of four basal doses of phosphorus, i.e., 15 kg P/ha (B_{P15}), 30 kg P/ha (B_{P30}), 45 kg P/ha (B_{P45}) and 60 kg P/ha (B_{P60}) and presowing seed treatment with graded aqueous pyridoxine solution, viz., water soaked (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3) pyridoxine alone and in combination, was studied on growth characteristics, net assimilation rate, leaf nitrate reductase activity, leaf NPK content, yield attributes, seed yield and seed protein content of lentil var.T-36. The data are summarised in Table 17-22 and are briefly described below :

4.2.1 Growth characteristics

Five growth parameters, namely, root length, root nodule number, root fresh weight, root dry weight and leaf number, were studied at 60, 90 and 120d after sowing. The data are given in Tables 17-19.

4.2.1.1 Root length per plant

The effect of basal phosphorus application, pre-sowing seed treatment with pyridoxine and their interaction on root length was found significant at all the three growth stages (Table 17).

When the effect of phosphorus was taken into consideration, treatment B_{P30} proved optimum but was statistically equal to B_{P45} at 60 and 90d. The lowest dose (B_{P15}) gave the minimum value at 60 and 120d while at 90d the effect was equalled by B_{P60}.

The pre-sowing seed treatment S_2 resulted in longest roots at all growth stages. The value differed significantly with those for all other treatments at all stages, except at 60d when it was at par with that for S_1.

The interaction B_{P30} x S_1 gave maximum root length at all growth stages. However, this value was statistically equal

Table 17. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on root length and root nodule number per plant of lentil var. T-36 (Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Root length (cm)														
B_{P15}	4.33	5.33	6.06	4.66	5.10	6.21	6.85	7.73	6.51	6.83	7.37	8.33	9.00	7.66	8.09
B_{P30}	5.00	7.33	7.00	5.33	6.17	6.72	9.33	9.16	7.33	8.14	8.23	10.33	10.16	8.46	9.30
B_{P45}	4.08	7.07	7.66	5.67	6.12	6.09	8.46	10.08	7.53	8.04	7.19	9.62	10.66	8.83	9.08
B_{P60}	4.00	6.33	6.32	5.66	5.58	6.06	7.94	7.88	7.07	7.24	6.66	9.00	9.20	8.50	8.34
Mean	4.35	6.52	6.75	5.33		6.27	8.15	8.71	7.11		7.36	9.32	9.76	8.36	
C.D. at 5%	B = 0.386, S = 0.386, BxS = 0.772					B = 0.54, S = 0.54, BxS = 1.08					B = 0.426, S = 0.426, BxS = 0.852				
	Root nodule number														
B_{P15}	7.50	6.66	8.33	6.36	7.21	12.60	14.00	15.33	13.33	13.82	6.55	5.80	9.66	4.66	6.67
B_{P30}	6.50	15.00	14.66	7.00	10.79	13.00	18.33	17.00	14.60	15.73	4.00	12.88	11.33	7.55	8.94
B_{P45}	5.03	13.00	16.66	8.25	10.74	10.00	16.66	19.00	14.66	15.08	3.89	11.00	12.87	9.00	9.19
B_{P60}	5.50	10.66	11.50	7.66	8.83	10.00	15.66	16.00	14.60	14.07	3.66	10.50	10.66	8.33	8.29
Mean	6.13	11.33	12.79	7.32		11.40	16.16	16.83	14.30		4.53	10.05	11.13	7.39	
C.D. at 5%	B = 0.62, S = 0.62, BxS = 1.24					B = 0.68, S = 0.68, BxS = 1.36					B = 0.82, S = 0.82, BxS = 1.63				

to those for B_{P30} x S_2, B_{P45} x S_1 and B_{P45} x S_2 at 60d; and at 90 and 120d to those for B_{P30} x S_2 and B_{P45} x S_2. The combined dose of B_{P30} and S_1 showed an increase of 69.28% at 60d, 50.24% at 90d and 40.16% at 120d over B_{P15} x S_W.

4.2.1.2 Root nodule number per plant

The effect of basal application of phosphorus and pre-sowing seed treatment with pyridoxine alone, as well as of their interaction on root nodule number was significant at all growth stages (Table 17).

Regarding the effect of phosphorus, it was noted that B_{P30} equalled by B_{P45} produced maximum root nodules at all growth stages. B_{P15} gave lowest value at all stages; but, at 90d it was at par with B_{P60}.

Among pre-sowing seed treatments, S_2 gave the maximum and S_W, the minimum value at all growth stages.

The interaction B_{P30} x S_1 (equalled by B_{P45} x S_2) proved best at 60 and 90d. However, at 120d, the interaction B_{P30} x S_1 was at par with B_{P30} x S_2 also. The optimum interaction (B_{P30} x S_1) showed an increase of 100, 45.48 and 96.66% at 60, 90 and 120d respectively over B_{P15} x S_W.

4.2.1.3 Root fresh weight per plant

The effects of basal application of phosphorus and of pyridoxine treatment alone as well as of their interaction were significant at all growth stages (Table 18).

Table 18. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on fresh and dry weights of root per plant of lentil var.T-36 (Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean
						Fresh weight of root(g)									
B_{P15}	0.040	0.043	0.050	0.040	0.043	0.060	0.070	0.090	0.070	0.073	0.100	0.110	0.133	0.016	0.112
B_{P30}	0.043	0.063	0.057	0.047	0.053	0.067	0.120	0.123	0.073	0.096	0.110	0.187	0.177	0.120	0.149
B_{P45}	0.037	0.053	0.087	0.047	0.056	0.057	0.120	0.133	0.090	0.100	0.097	0.150	0.200	0.130	0.144
B_{P60}	0.033	0.050	0.053	0.047	0.046	0.050	0.110	0.110	0.083	0.088	0.080	0.140	0.140	0.120	0.120
Mean	0.038	0.052	0.062	0.045		0.059	0.105	0.114	0.079		0.097	0.147	0.163	0.119	
C.D. at 5%	B = 0.008, S = 0.008, BxS = 0.016					B = 0.007, S = 0.007, BxS = 0.014					B = 0.013, S = 0.013, BxS = 0.025				
						Dry weight of root (g)									
B_{P15}	0.033	0.040	0.043	0.033	0.038	0.050	0.060	0.073	0.052	0.059	0.060	0.030	0.100	0.070	0.078
B_{P30}	0.037	0.067	0.057	0.040	0.050	0.060	0.085	0.083	0.066	0.074	0.080	0.150	0.140	0.090	0.115
B_{P45}	0.030	0.050	0.073	0.043	0.049	0.050	0.076	0.093	0.070	0.072	0.050	0.130	0.150	0.100	0.108
B_{P60}	0.027	0.043	0.047	0.043	0.040	0.043	0.073	0.076	0.066	0.065	0.040	0.110	0.120	0.100	0.093
Mean	0.032	0.050	0.055	0.040		0.051	0.074	0.081	0.064		0.058	0.118	0.128	0.090	
C.D. at 5%	B = 0.007, S = 0.007, BxS = 0.014					B = 0.004, S = 0.004, BxS = 0.008					B = 0.014, S = 0.014, BxS = 0.028				

B_{P30} equalled by B_{P45} gave maximum root fresh weight at all growth stages. Among soaking treatments, S_2 produced maximum fresh weight of root at all growth stages and the value differed critically from those for all other treatments.

When the interaction effect was taken into consideration, it was observed that $B_{P45} \times S_2$ produced maximum fresh weight of root at all growth stages and the value differed significantly from those for all other combinations at 60d. However, it was at par with $B_{P30} \times S_1$, $B_{P30} \times S_2$ and $B_{P45} \times S_1$ at 90d and with $B_{P30} \times S_1$ and $B_{P30} \times S_2$ at 120d respectively. Moreover, at 60d the effect of $B_{P30} \times S_1$ was found second to $B_{P45} \times S_2$. At this stage, the interactions $B_{P45} \times S_2$ and $B_{P30} \times S_1$ showed an increase of 117.5 and 57.5% respectively over $B_{P15} \times S_W$ which gave the lowest value. At 90 and 120d $B_{P30} \times S_1$ showed an increase of 100.00 and 87.00% in fresh weight of root respectively over $B_{P15} \times S_W$.

4.2.1.4 Root dry weight per plant

The effects of phosphorus and pyridoxine treatment alone and of their interaction were significant on the dry weight of root at all growth stages (Table 18).

When the effect of phosphorus was considered, it was found that B_{P30} produced maximum dry weight and the value differed significantly from those for all other phosphorus levels except B_{P45} at all growth stages. On the other hand,

B_{P15} gave the lowest value at all growth stages, except at 60d, when it was equal to that for B_{P60}.

With respect to pre-sowing seed treatment with pyridoxine solutions S_2 proved best for root dry weight at all growth stages; but it was equalled by S_1 at 60 and 120d.

The interaction $B_{P30} \times S_1$ showed maximum value at all growth stages. However, the value was statistically equal to that for $B_{P45} \times S_2$ at 60d and 90d; while at 120d its effect was at par with those of $B_{P30} \times S_2$, $B_{P45} \times S_1$ and $B_{P45} \times S_2$. The interaction $B_{P30} \times S_1$ showed an increase for 103.03% at 60d; 70.00% at 90d and 150.00% at 120d over $B_{P15} \times S_W$.

4.2.1.5 Leaf number per plant

The effects of phosphorus and pyridoxine treatments and of their interaction on leaf production were found significant at all growth stages (Table 19).

Regarding the effect of phosphorus, it was noted that B_{P30} equalled by B_{P45} produced maximum leaves at all growth stages. Treatment B_{P15} produced the lowest number of leaves, the effect being critically different from those of all other basal doses of phosphorus.

Regarding soaking treatment, S_2 proved best and the S_W (control) showed poorest effect at all growth stages. The values for all treatment at these stages differed critically from each other.

Table 19. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, netassimilation rate (NAR) and nitrate reductase activity (NRA) of lentil var. T-36 (Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Leaf number														
B_{P15}	30.63	36.66	47.00	33.56	36.95	71.66	74.63	93.33	72.29	77.98	68.00	74.66	83.03	69.66	73.84
B_{P30}	35.00	68.36	60.66	38.33	50.59	75.37	115.31	108.00	78.37	94.26	70.35	97.57	93.36	76.63	84.48
B_{P45}	30.70	54.30	71.00	41.33	49.33	69.03	104.00	120.33	89.35	95.68	65.63	90.03	98.04	82.37	84.02
B_{P60}	29.99	49.00	50.66	38.89	42.14	58.00	94.00	98.66	80.63	82.82	50.06	86.63	87.96	78.50	75.79
Mean	31.58	52.08	57.33	38.03		68.52	96.99	105.08	80.16		63.51	87.22	90.60	76.79	
C.D. at 5%	B = 2.38, S = 2.38, BxS = 4.75					B = 3.47, S = 3.47, BxS = 6.93					B = 1.44, S = 1.44, BxS = 2.87				
	NAR ($x10^{-4}$ g/cm^2/d)														
	(60-90d interval)					(90-120d interval)									
B_{P15}	3.236	3.936	4.221	3.651	3.761	1.877	1.983	2.129	1.947	1.984					
B_{P30}	3.729	5.168	5.129	3.928	4.501	1.949	2.441	2.330	2.007	2.182					
B_{P45}	2.969	4.784	5.741	4.187	4.420	1.370	2.305	2.460	2.101	2.059					
B_{P60}	2.722	4.386	4.685	3.985	3.945	1.215	2.140	2.286	2.052	1.923					
Mean	3.164	4.569	4.944	3.950		1.603	2.217	2.301	2.027						
C.D. at 5%	B = 0.29, S = 0.29, BxS = 0.58					B = 0.012, S = 0.012, BxS = 0.024									
	NRA (n mol NO_2^-/g/h)														
B_{P15}	107.84	118.28	124.37	111.53	115.50	79.57	96.65	107.68	83.95	91.91	59.07	45.77	77.45	45.34	56.91
B_{P30}	116.93	146.02	139.57	121.57	131.02	87.44	118.97	113.44	101.40	105.31	54.42	98.43	101.44	64.23	79.63
B_{P45}	107.94	133.38	146.32	122.90	127.64	75.50	113.86	119.34	103.96	103.17	43.33	87.01	105.80	73.54	77.42
B_{P60}	103.36	127.89	127.64	122.45	120.34	73.66	107.56	102.67	103.33	98.81	41.86	81.33	87.75	68.63	69.90
Mean	109.02	131.38	134.48	119.61		78.99	109.26	112.78	98.16		49.67	78.14	93.11	62.94	
C.D. at 5%	B = 1.34, S = 1.34, BxS = 2.68					B = 0.31, S = 0.31, BxS = 0.62					B = 1.66, S = 1.66, BxS = 3.32				

Among different interactions, $B_{P30} \times S_1$ gave maximum number of leaves at all growth stages and the value was critically different from those for all other treatments except $B_{P45} \times S_2$. Application of $B_{P30} \times S_1$ increased leaf number by 123.18% at 60d; 60.91% at 90d and 43.49% at 120d compared with $B_{P15} \times S_W$ at the respective growth stage.

4.2.2 Net assimilation rate (NAR)

Net assimilation rate was computed for 60-90 and 90-120d periods and was significantly affected by phosphorus and pyridoxine treatments alone and by their interaction (Table 19).

When the effect of phosphorus was considered, B_{P30} proved best at each of the two interval. However, at the first interval, this treatment was statistically equal to B_{P45} in its effect.

In relation to soaking, S_2 was found to be responsible for the highest value at both intervals. S_W (control) exhibited the poorest effect on NAR at both intervals and its values were critically different from those for the other seed treatments.

Among various interactions, $B_{P30} \times S_1$ and $B_{P45} \times S_2$ (showing equal effect) gave significantly higher value in comparison with all other interactions at both intervals. $B_{P30} \times S_1$ gave an increase of 59.70 and 30.05% at 60-90 and 90-120d respectively over their respective $B_{P15} \times S_W$ values.

4.2.3 Nitrate reductase activity (NRA)

Leaf nitrate reductase activity was measured at 60, 90 and 120d. The effect of phosphorus and pyridoxine treatments and of their interaction significantly affected activity of this enzyme at all stages (Table 19).

On comparing the values given by phosphorus treatments, maximum NRA was noted in B_{P30} and the value differed critically from those for all other treatments at all growth stages, except at 120d when it was equalled by B_{P45}. B_{P15} (control) gave significantly lowest value.

Taking the effect of pyridoxine treatment into consideration, it was revealed that S_2 and S_W (control) showed significantly maximum and minimum enzyme activity at all growth stages.

Among the interactions, B_{P30} x S_1 proved best at all growth stages. However, the value was statistically equal to that for B_{P45} x S_2 at 60 and 90d; but at 120d, B_{P45} x S_2, followed by B_{P30} x S_1, gave the highest value which differed critically from the values for other treatments. The interaction B_{P30} x S_1 increased enzymatic activity over B_{P15} x S_W by 35.40 and 49.89% at 60 and 90d respectively. However, at 120d B_{P45} x S_2 and B_{P30} x S_1 gave an increase of 79.11 and 71.73% respectively.

4.2.4 Leaf NPK content

Leaf nitrogen, phosphorus and potassium contents were estimated at 60, 90 and 120d and noted to be significantly affected by phosphorus and pyridoxine treatments separately as well as in combination (Table 20).

4.2.4.1 Nitrogen

It is evident from Table 20 that basal application of 30 kg P per ha (B_{P30}) increased nitrogen content of leaves most at all growth stages. However, its value was at par with B_{P45} at 60d and with B_{P45} and B_{P60} at 120d respectively. B_{P15} (control) gave the lowest value at all stages.

When the effects of pyridoxine treatment were considered, S_2 proved best at all growth stages, differing from the rest of the treatments. On the other hand, S_W (control) showed the poorest effect.

Regarding the interaction effect, $B_{P30} \times S_1$ gave the highest leaf nitrogen content at 60 and 90d and the value differed significantly from those for other interactions except $B_{P45} \times S_2$ at 60d. At 120d $B_{P30} \times S_1$ was equal to $B_{P30} \times S_2$ and $B_{P45} \times S_2$ and differed critically from all other interactions in its effect. $B_{P30} \times S_1$ increased leaf nitrogen content by 51.29, 81.16 and 53.04% at 60, 90 and 120d, the increase due to $B_{P45} \times S_2$ at 90d being 99.32%, over $B_{P15} \times S_W$.

Table 20. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of lentil var. T-36

(Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)														
	60					90					120				
	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
								Nitrogen (%)							
B_{P15}	4.25	4.84	5.49	4.47	4.76	2.92	2.48	4.06	2.43	2.97	2.30	1.51	2.72	1.48	2.00
B_{P30}	4.64	6.43	6.23	5.09	5.60	2.64	5.29	5.09	3.28	4.08	1.50	3.52	3.23	1.71	2.49
B_{P45}	4.24	6.08	6.64	5.23	5.55	2.49	5.07	5.82	3.80	4.30	1.31	3.07	3.50	2.36	2.56
B_{P60}	4.22	5.67	5.80	5.07	5.19	2.26	4.28	4.52	3.62	3.67	1.33	3.08	3.01	3.05	2.62
Mean	4.34	5.76	6.04	4.97		2.58	4.28	4.87	3.28		1.61	2.80	3.12	2.15	
C.D. at 5%	B = 0.107, S = 0.107, BxS = 0.214					B = 0.175, S = 0.175, BxS = 0.350					B = 0.204, S = 0.204, BxS = 0.409				
								Phosphorus (%)							
B_{P15}	0.340	0.380	0.460	0.370	0.388	0.240	0.180	0.270	0.200	0.223	0.150	0.110	0.160	0.120	0.135
B_{P30}	0.380	0.580	0.560	0.400	0.480	0.220	0.400	0.360	0.240	0.305	0.150	0.240	0.200	0.120	0.178
B_{P45}	0.300	0.540	0.590	0.430	0.465	0.130	0.340	0.420	0.250	0.285	0.100	0.210	0.260	0.160	0.183
B_{P60}	0.290	0.300	0.510	0.420	0.350	0.130	0.280	0.300	0.243	0.238	0.100	0.180	0.200	0.150	0.158
Mean	0.328	0.450	0.530	0.405		0.180	0.300	0.338	0.233		0.125	0.185	0.205	0.138	
C.D. at 5%	B = 0.018, S = 0.018, BxS = 0.035					B = 0.025, S = 0.025, BxS = 0.051					B = 0.012, S = 0.012, BxS = 0.024				
								Potassium (%)							
B_{P15}	3.40	3.70	4.30	3.50	3.73	2.60	2.90	3.40	2.70	2.90	1.43	1.08	1.80	1.20	1.38
B_{P30}	3.53	5.40	5.20	3.80	4.48	3.80	4.80	4.60	3.00	3.80	1.67	2.50	2.30	1.41	1.97
B_{P45}	3.63	5.00	5.60	4.20	4.51	2.60	4.40	5.90	3.40	4.08	1.33	2.10	2.70	1.60	1.93
B_{P60}	3.20	4.50	4.80	3.80	4.08	2.30	3.70	3.20	3.20	3.10	0.95	2.00	2.10	1.60	1.66
Mean	3.44	4.65	4.98	3.83		2.58	3.95	4.28	3.08		1.35	1.92	2.23	1.45	
C.D. at 5%	B = 0.30, S = 0.30, BxS = 0.60					B = 0.68, S = 0.68, BxS = 1.36					B = 0.27, S = 0.27, BxS = 0.54				

4.2.4.2 Phosphorus

The effect of phosphorus and pyridoxine treatments alone as well as of their interaction on the phosphorus content of leaves was significant at all stages (Table 20).

Considering the effect of phosphorus application at all three stages, the percentage of phosphorus in the leaves was maximum in treatment B_{P30} which differed significantly from others but was equalled by B_{P45}. Application of B_{P15} and B_{P60} (showing equal effect) had lowest value at 60 and 90d; but, at 120d, B_{P15} gave the lowest value that differed critically from those of all other treatments.

Regarding the effect of pyridoxine treatments, S_2 produced the maximum phosphorus content of leaves at all growth stages and S_W showed the poorest effect.

Among various combinations, $B_{P30} \times S_1$ gave maximum value at all growth stages. However, the value was at par with those of $B_{P30} \times S_2$ and $B_{P45} \times S_2$ at 60d and with $B_{P45} \times S_2$ at 90 and 120d. The interaction $B_{P30} \times S_1$ gave an increase in leaf phosphorus content of 70.59% at 60d, 66.67% at 90d and 60% at 120d over the $B_{P15} \times S_W$.

4.2.4.3 Potassium

Like nitrogen and phosphorus content, potassium concentration in leaves was significantly affected by the application of phosphorus and pyridoxine alone and by their interaction at all three stages (Table 20).

Regarding the effect of phosphorus on potassium content of leaves, B_{P30} (equalled by B_{P45}) proved best at all growth stages.

Among various soaking treatments, S_2 gave maximum potassium content of leaves and the value differed significantly from all treatments at 60 and 120d but was equal to that for S_1 at 90d. S_W (control) gave the lowest value at all stages.

Taking the interaction effect into consideration, it was revealed that $B_{P30} \times S_1$ gave the best results at all growth stages. However, the value was equalled by $B_{P30} \times S_2$, $B_{P45} \times S_1$ and $B_{P45} \times S_2$ at 60d and, at 90 and 120d, by the interactions $B_{P30} \times S_2$, $B_{P45} \times S_2$. The increase due to $B_{P30} \times S_1$ over $B_{P15} \times S_W$ was 58.82% at 60d, 84.62% at 90d and 74.83% at 120d.

4.2.5 Yield characteristics

Five yield parameters (pod number/plant, pod length, seed number/pod, 1,000 seed weight and seed yield) were studied at harvest. The effect of phosphorus dressing,pyridoxine treatment and of their interaction was significant on all yield parameters, except the interaction effect on 1,000 seed weight. The data are given in Tables 21-22 and are summarised below:

4.2.5.1 Pod number per plant

With regard to the effect of phosphorus, B_{P30} (equalled by B_{P45}) produced maximum pods and the value differed significantly from those for the remaining phosphorus treatments.

Of the various doses of pyridoxine treatments, S_2 proved best. Each pyridoxine treatment differed critically from the other in its effect on this parameter. The lowest value was given by the water-soaked control (S_W).

Among various interactions, the effect of $B_{P30} \times S_1$ was maximum which was at par with that for $B_{P45} \times S_2$. The values recorded for these two combinations significantly differed from those for the others (Table 21). The interaction $B_{P30} \times S_1$ gave an increase of 95.52% over $B_{P15} \times S_W$.

4.2.5.2 Pod length

The longest pods were produced as a results of the application of B_{P30} and value differed significantly from those for the rest of the treatments except for B_{P45}. Control (B_{P15}) had the poorest effect on pod length.

Regarding the effect of pyridoxine treatments, S_2 produced longest pods and the value significantly differed from those for all remaining treatments. Control (S_W) gave the poorest result.

Table 21. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of lentil var. T-36

(Mean of three replicates)

Basal treatments (Kg P/ha)	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Pod number/plant					Pod length (cm)					Seed number/pod				
B_{P15}	70.24	80.14	100.24	72.33	80.74	0.790	0.820	0.900	0.800	0.828	1.03	1.62	1.80	1.08	1.38
B_{P30}	78.93	137.33	112.66	84.53	103.36	0.810	1.020	0.950	0.830	0.903	1.25	1.92	1.87	1.75	1.70
B_{P45}	61.66	107.88	144.64	92.55	101.68	0.770	0.930	1.050	0.880	0.908	1.00	1.85	1.93	1.79	1.64
B_{P60}	60.44	102.21	105.33	92.33	90.08	0.710	0.900	0.920	0.871	0.850	0.99	1.81	1.81	1.77	1.60
Mean	67.82	106.89	115.72	85.44		0.770	0.918	0.955	0.845		1.07	1.80	1.85	1.60	
C.D. at 5%	B = 3.67, S = 3.67, BxS = 7.34					B = 0.016, S = 0.016, BxS = 0.031					B = 0.023, S = 0.023, BxS = 0.047				

With regard to the interaction effect, application of $B_{P30} \times S_1$ gave maximum value which was at par with that for $B_{P45} \times S_2$, but significantly differed from those for other interactions (Table 21). $B_{P30} \times S_1$ gave an increase of 29.11% over $B_{P15} \times S_W$.

4.2.5.3 Seed number per pod

The maximum seed number was noted with the application of B_{P30} and the effect of each level of phosphorus differed critically from the other. The lowest value was given by B_{P15} (control).

With regard to the effect of pyridoxine treatment, S_2 produced maximum seeds and the value differed significantly from those for the remaining pyridoxine treatments. S_W (control) gave the lowest number of seeds per pod.

Among various interaction treatments, application of $B_{P30} \times S_1$ gave maximum value which was at par with that for $B_{P45} \times S_2$ but significantly differed from all other interactions (Table 21). The interaction $B_{P30} \times S_1$ gave an increase of 86.41% over $B_{P15} \times S_W$.

4.2.5.4 1,000 seed weight

As mentioned earlier, the effect of phosphorus and pyridoxine treatments alone was significant for 1,000 seed weight. However, their interaction effect was non-significant (Table 22).

Table 22. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of lentil var.T-36

(Mean of three replicates)

Basal treatments (kg P/ha)	Soaking treatments (% pyridoxine)														
	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean
	1,000 seed weight (g)					Seed yield (q/ha)					Protein content (%)				
B_{P15}	19.93	20.61	21.08	20.00	20.41	18.10	19.86	21.49	19.62	19.77	20.80	20.00	21.50	20.40	20.68
B_{P30}	20.53	21.30	21.28	20.88	21.00	19.74	23.72	23.61	20.09	21.79	20.20	24.60	23.60	20.20	22.15
B_{P45}	19.88	21.23	21.36	20.98	20.86	17.82	23.50	24.65	21.41	21.85	20.00	22.80	24.20	20.80	21.95
B_{P60}	19.48	21.15	21.19	20.96	20.70	16.46	22.88	23.33	21.29	20.99	19.80	21.40	21.80	20.60	20.90
Mean	19.96	21.07	21.23	20.71		18.03	22.49	23.27	20.60		20.20	22.20	22.78	20.50	
C.D. at 5%	B = 0.39, S = 0.39, BxS = N.S.					B = 0.47, S = 0.47, BxS = 0.93					B = 0.52, S = 0.52, BxS = 1.04				

N.S. = Non-significant

Among various phosphorus levels, B_{P30} produced heaviest seeds; but the value was at par with those for B_{P45} and B_{P60}. The control (B_{P15}) gave the lighest seeds. Regarding the response of pyridoxine soaking, it was found that S_2 gave maximum value. However, it was at par with that for S_1. S_W gave the poorest effect.

4.2.5.5 Seed yield

As mentioned earlier, the effect of phosphorus and pyridoxine treatments and of their interaction on seed yield was significant (Table 22).

Among various phosphorus treatments, B_{P30} (equalled by B_{P45}) gave the maximum yield. The lowest yield was recorded in B_{P15} (control).

Pertaining to the pyridoxine treatments, S_2 gave the maximum seed yield. Control (S_W) gave the lowest yield.

Regarding the interaction effect, it was revealed that $B_{P30} \times S_1$ gave highest seed yield. However, the value was statistically equal to that for $B_{P45} \times S_2$ but differed significantly from those for the rest of the interactions. The interaction $B_{P30} \times S_1$ gave an increase of 31.05% over $B_{P15} \times S_W$.

4.2.6 Seed protein content

It is evident from Table 22 that maximum seed protein content was given by B_{P30} but was equalled by B_{P45}. The lowest protein content was recorded in the control (B_{P15}).

With regard to the effect of pyridoxine treatments, S_2 produced maximum protein content and its value was critically different from those of the remaining pyridoxine treatments. Control (S_W) gave the lowest value which was statistically equal to that for S_3.

Regarding the interaction effect, it emerged that $B_{P30} \times S_1$ gave the highest protein content. However, its value was statistically equal to that for $B_{P30} \times S_2$ and $B_{P45} \times S_2$ but differed critically from those for the rest of the interactions (Table 22). The interaction $B_{P30} \times S_1$ gave an increase of 18.27% in protein content of seed compared with $B_{P15} \times S_W$.

In conclusion, it may be noted that, among soaking treatments, 0.2 per cent aqueous pyridoxine solution (S_1) and, among basal treatments, 30 kg P in the presence of 45 kg N and 30 kg K/ha would ensure highest yields with least investment.

4.3 Experiment 3

In this factorial randomised field experiment on lentil var.T-36, the treatments consisted of (i) two basal doses of nitrogen, i.e., 15 kg N/ha (B_{N15}) and 30 kg N/ha (B_{N30}), both supplemented with foliar spray of three doses of aqueous solution of urea nitrogen, viz., 0 (control), 5 and 10 kg N/ha (F_W, F_{N5} and F_{N10}) at pod filling stage, i.e., 100d and

(ii) soaking in two levels of aqueous pyridoxine solution, i.e., 0.2 and 0.3% (S_1 and S_2 respectively). The basal doses of nitrogen and dilutions of pyridoxine solution were selected on the basis of the results of Experiment 1.

The same parameters, as indicated in Experiment 1, were studied for growth, net assimilation rate, nitrate reductase activity, leaf NPK content, yield and quality characteristics. The data are presented in Tables 23-27 and are summarised below:

4.3.1 Growth characteristics

In this experiment, the sampling was done 20d after applying the foliar spray (120d) to assess the growth performance of the crop as affected by various treatments. The data are presented in Tables 23-24 and are briefly described below.

4.3.1.1 Root length per plant

The effects of nitrogen treatment, soaking treatment and their interaction were significant for this parameters (Table 23).

Regarding the effect of nitrogen treatments, maximum root length was given by the plants receiving B_{N15} + F_{N5}. However, its value was at par with that for $B_{N15}+F_{N10}$. Regarding soaking treatment, S_2 gave significantly higher value than S_1.

Regarding the interaction effect of nitrogen and pyridoxine soaking, it was observed that $(B_{N15}+F_{N5}) \times S_2$ proved

Table 23. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on root length, root nodule number, fresh and dry weights of root per plant of lentil var. T-36 studied at 120d

(Mean of three replicates)

Basal + Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)											
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Root length (cm)			Root nodule number			Fresh weight of root(g)			Dry weight of root(g)		
$B_{N15} + F_W$	10.00	10.46	10.23	8.33	8.33	8.33	0.733	0.933	0.833	0.100	0.101	0.101
$B_{N30} + F_W$	9.66	9.33	9.50	7.42	6.33	6.88	0.833	0.833	0.833	0.100	0.090	0.095
$B_{N15} + F_{N5}$	10.33	14.24	12.29	8.43	8.83	8.63	1.33	1.76	1.55	0.130	0.160	0.145
$B_{N30} + F_{N5}$	8.66	8.66	8.66	5.00	5.33	5.17	0.966	0.933	0.950	0.086	0.086	0.086
$B_{N15} + F_{N10}$	13.33	11.00	12.17	8.64	8.46	8.55	1.70	1.53	1.62	0.136	0.133	0.135
$B_{N30} + F_{N10}$	7.64	8.66	8.15	3.67	3.88	3.78	0.733	0.733	0.733	0.076	0.081	0.079
Mean	9.94	10.39		6.92	6.86		1.05	1.12		0.105	0.109	
C.D. at 5%	BF=0.60, S=0.35, BFxS=0.85			BF=0.17, S=N.S., BFxS=0.24			BF=0.061, S=0.035, BFxS=0.086			BF=0.025, S=N.S., BFxS=0.035		

N.S.= Non-significant

optimum. This interaction increased root length by 42.40% over $(B_{N15}+F_W) \times S_1$.

4.3.1.2 Root nodule number per plant

The effect of nitrogen and of its interaction with pyridoxine on the number of nodules per plant was significant. However, seed soaking resulted in equal effect of both levels of pyridoxine (Table 23).

As is evident from Table 23, the effect of $B_{N15}+F_{N5}$ was least but was statistically equal to that of $B_{N15}+F_{N10}$. Application of $B_{N30}+F_W$ showed the poorest effect.

Among the various interactions, $(B_{N15}+F_{N5}) \times S_2$ gave higher number of nodules in comparison to the other interactions, except $(B_{N15}+F_{N10}) \times S_1$. The increase in nodule production due to $(B_{N15}+F_{N5}) \times S_2$ over $(B_{N15}+F_W) \times S_1$ was 6.00 per cent.

4.3.1.3 Root fresh weight per plant

The effect of nitrogen, pyridoxine and their interaction on the fresh weight of root per plant was significant (Table 23).

$B_{N15}+F_{N5}$ gave maximum root fresh weight but it was equalled by $B_{N15}+F_{N10}$. Fresh weight of root given by S_2 was significantly higher than that given by S_1.

Pertaining to the interaction effect, maximum fresh weight of root was recorded in $(B_{N15}+F_{N5}) \times S_2$. However, in its effect, it was equalled by $(B_{N15}+F_{N10}) \times S_1$. The interaction $(B_{N15}+F_{N5}) \times S_2$ increased the fresh weight of root by 140.11% over $(B_{N15}+F_W) \times S_1$.

4.3.1.4 Root dry weight per plant

The effect of nitrogen application and of its interaction with pyridoxine soaking treatment was found significant. However, the two concentrations of pyridoxine (S_1 and S_2) did not produce significantly different dry weight of root (Table 23).

Application of $B_{N15}+F_{N5}$ proved optimum for root dry matter production. Its effect was however, statistically equal to that of $B_{N15}+F_{N10}$.

Regarding the interaction effect, $(B_{N15}+F_{N5}) \times S_2$, showing equal effect with those for $(B_{N15}+F_{N5}) \times S_1$, $(B_{N15}+F_{N10}) \times S_1$ and $(B_{N15}+F_{N10}) \times S_2$ gave a higher value than did all other interactions. Treatment $(B_{N15}+F_{N5}) \times S_2$ increased dry weight of root by 60.00% over $(B_{N15}+F_W) \times S_1$.

4.3.1.5 Leaf number per plant

The effect of application of nitrogen, pyridoxine soaking and their interaction on leaf production was significant (Table 24).

$B_{N15}+F_{N5}$ produced significantly more leaves in comparison to other nitrogen treatments, except $B_{N15}+F_{N10}$. Among the two levels of pyridoxine, S_2 produced more leaves in comparison to S_1.

Table 24. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, net assimilation rate (NAR) and nitrate reductase ascitivy (NRA) of lentil var.T-36 studied at 120d

(Mean of three replicates)

Basal+Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Leaf number			NAR ($\times 10^{-4}$ g/cm^2/d)			NRA (nmol NO_2^-/g/h)		
$B_{N15} + F_W$	107.34	107.67	107.51	2.11	2.17	2.14	62.37	62.46	62.42
$B_{N30} + F_W$	85.33	94.00	89.67	1.25	1.24	1.25	60.52	60.09	60.31
$B_{N15} + F_{N5}$	112.33	144.67	128.50	2.19	2.89	2.54	64.38	76.39	70.39
$B_{N30} + F_{N5}$	80.33	83.33	81.83	1.12	1.12	1.12	55.36	58.77	57.07
$B_{N15} + F_{N10}$	140.33	112.43	126.38	2.69	2.37	2.53	73.87	78.65	71.26
$B_{N30} + F_{N10}$	52.66	56.00	54.33	1.07	1.11	1.09	54.37	54.48	54.43
Mean	96.39	99.69		1.74	1.82		61.81	63.47	
C.D. at 5%	BF=5.13, S=2.96, BFxS=7.26			BF=0.100, S=0.057, BFxS=0.142			BF=2.46, S=1.42, BFxS=3.47		

Regarding the interaction effect, $(B_{N15}+F_{N5}) \times S_2$ produced maximum leaves. However, the value was equalled by $(B_{N15}+F_{N10}) \times S_1$. The interaction, $(B_{N15}+F_{N5}) \times S_2$ gave an increase of 34.77% over $(B_{N15}+F_W) \times S_1$.

4.3.2 Net assimilation rate (NAR)

Net assimilation rate was estimated only for 90-120d interval and the effect of nitrogen, soaking treatment and of their interaction was significant (Table 24).

Application of $B_{N15}+F_{N5}$ (showing equal effect with $B_{N15}+F_{N10}$) gave higher value of NAR in comparison to other treatments. Plants receiving $B_{N30}+F_{N5}$ and $B_{N30}+F_{N10}$ nitrogen gave lowest (equal) values. With regard to the soaking treatments S_2 registered a higher value than S_1.

Regarding the interaction effect, $(B_{N15}+F_{N5}) \times S_2$ proved best. This interaction enhanced NAR by 36.96% over $(B_{N15}+F_W) \times S_1$.

4.3.3 Nitrate reductase activity (NRA)

Nitrate reductase activity was estimated in leaves at 120d. The effects of nitrogen, pyridoxine soaking and their interaction were found to be significant (Table 24).

Regarding the effect of nitrogen treatment, it emerged that $B_{N15}+F_{N5}$, equalled by $B_{N15}+F_{N10}$, was best. Soaking in S_2 showed significantly higher NRA than that in S_1.

Among different interactions, $(B_{N15}+F_{N5}) \times S_2$ proved optimum and gave critically different value than those for all other interactions, except $(B_{N15}+F_{N10}) \times S_1$. An increase of 22.48% was recorded in $(B_{N15}+F_{N5}) \times S_2$ over $(B_{N15}+F_W) \times S_1$.

4.3.4 Leaf NPK content

Like the other characteristics noted above, leaf NPK content was also estimated at 120d. The NPK content of leaves was found to be significant affected by nitrogen treatment, pyridoxine soaking and their interaction (Table 25).

Regarding nitrogen application, $B_{N15}+F_{N5}$ (equalled by $B_{N15}+F_{N10}$) proved best for NPK content in leaves. Whereas, regarding the soaking of seeds in pyridoxine solution, S_2 showed significantly higher value for leaf NPK than S_1.

Among various interactions $(B_{N15}+F_{N5}) \times S_2$ gave the highest NPK content of leaves but the value for N and P was at par with that noted in $(B_{N15}+F_{N10}) \times S_1$. The interaction $(B_{N15}+F_{N5}) \times S_2$ enhanced N, P and K content of leaves by 24.14, 29.23 and 32.33% respectively over $(B_{N15}+F_W) \times S_1$.

4.3.5 Yield characteristics

Five yield parameters (pod number/plant, pod length, seed number/pod, 1,000 seed weight and seed yield) were studied at harvest. All of these were significantly affected by nitrogen, pyridoxine soaking and their interaction, except pod length and 1,000 seed weight (Tables 26-27).

Table 25. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of lentil var.T-36 studied at 120d

(Mean of three replicates)

Basal+Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
$B_{N15} + F_W$	2.32	2.66	2.49	0.366	0.410	0.388	2.66	2.75	2.71
$B_{N30} + F_W$	2.30	2.22	2.26	0.348	0.340	0.344	2.53	2.53	2.53
$B_{N15} + F_{N5}$	2.66	2.88	2.77	0.424	0.473	0.449	3.20	3.52	3.36
$B_{N30} + F_{N5}$	1.34	1.53	1.44	0.264	0.333	0.299	2.33	2.35	2.34
$B_{N15} + F_{N10}$	2.84	2.67	2.76	0.467	0.429	0.448	3.33	3.24	3.29
$B_{N30} + F_{N10}$	1.23	1.32	1.28	0.226	0.233	0.230	2.23	2.30	2.27
Mean	2.12	2.21		0.349	0.370		2.71	2.78	
C.D. at 5%	BF=0.116, S=0.067, BFxS=0.164			BF=0.023, S=0.014, BFxS=0.033			BF=0.092, S=0.053, BFxS=0.130		

4.3.5.1 Pod number per plant

The effect of $B_{N15}+F_{N5}$ (showing equal effect with $B_{N15}+F_{N10}$) produced significantly more pods per plant than all other nitrogen treatments. On the other hand, soaking in S_2 gave a higher value than S_1.

Pertaining to the interaction effect of nitrogen and pyridoxine soaking treatments, $(B_{N15}+F_{N5}) \times S_2$ produced maximum pods (Table 26). This interaction increased pod production by 53.67% over $(B_{N15}+F_W) \times S_1$.

4.3.5.2 Pod length

As mentioned earlier, nitrogen treatment, pyridoxine soaking and their interaction did not significantly affect pod length in lentil (Table 26).

4.3.5.3 Seed number per pod

Regarding the different nitrogen treatments, $B_{N15}+F_{N10}$ exhibited optimum seed number per pod. Soaking in S_2 gave higher number of seeds per pod in comparison to S_1.

Regarding the interaction effect, $(B_{N15}+F_{N5}) \times S_2$, being at par with $(B_{N15}+F_{N10}) \times S_1$, gave significantly higher value than those for all other interactions (Table 26). The interaction, $(B_{N15}+F_{N5}) \times S_2$ increased number of seed per pod by 45.24% over $(B_{N15}+F_W) \times S_1$.

Table 26. Effect of basal and foliar application on nitrogen (BF) and pre-sowing seed treatment with pyridoxine(S) on yield parameters of lentil var.T-36

(Mean of three replicates)

Basal+Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Pod number/plant			Pod length (cm)			Seed number/pod		
$B_{N15} + F_W$	126.66	142.43	134.55	0.833	0.864	0.849	1.26	1.33	1.30
$B_{N30} + F_W$	121.64	100.66	111.15	0.833	0.800	0.817	1.26	1.24	1.25
$B_{N15} + F_{N5}$	145.33	194.64	169.99	0.866	0.996	0.931	1.33	1.83	1.58
$B_{N30} + F_{N5}$	90.66	94.66	92.66	0.800	0.800	0.800	1.00	1.22	1.11
$B_{N15} + F_{N10}$	179.33	158.33	168.83	0.996	0.866	0.931	1.80	1.67	1.74
$B_{N30} + F_{N10}$	78.66	90.44	84.55	0.800	0.800	0.800	1.00	1.00	1.00
Mean	123.71	130.19		0.855	0.854		1.28	1.38	
C.D. at 5%	BF=8.95, S=5.17, BFxS=12.66			BF=N.S., S=N.S., BFxS=N.S.			BF=0.029, S=0.017, BFxS=0.041		

N.S. = Non-significant

4.3.5.4 1,000 seed weight

All nitrogen and pyridoxine treatments as well as their interactions seemed to affect the test weight of lentil equally (Table 27).

4.3.5.5 Seed yield

With regard to nitrogen treatment, application of $B_{N15}+F_{N5}$ (equalled by $B_{N15}+F_{N10}$) resulted in highest seed production and the value given by these two nitrogen treatments differed critically from those for the rest of the treatments. Among the pyridoxine treatments, S_2 proved better than S_1 for seed production in lentil.

As far as interaction effect of nitrogen and pyridoxine soaking treatment concerned, it was revealed that $(B_{N15}+F_{N5}) \times S_2$ proved best and the value differed significantly for those for other interactions (Table 27). This interaction $(B_{N15}+F_{N5}) \times S_2$ enhanced seed yield by 21.04% in comparison with $(B_{N15}+F_{N}) \times S_1$.

4.3.6 Seed protein content

Nitrogen treatment, $B_{N15}+F_{N10}$ proved optimum for protein content of seeds and the value recorded for this treatment differed critically from those for the rest of the nitrogen treatments. The soaking treatment S_2 resulted in significantly higher protein content of seeds than S_1.

Table 27. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of lentil var.T-36

(Mean of three replicates)

Basal+Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	1,000 seed weight (g)			Seed yield (g/ha)			Protein content (%)		
$B_{N15} + F_W$	21.33	21.33	21.33	14.40	14.60	14.50	22.36	22.46	22.41
$B_{N30} + F_W$	20.89	20.86	20.88	14.37	13.80	14.09	21.66	21.66	21.66
$B_{N15} + F_{N5}$	21.33	21.66	21.50	14.66	17.43	16.05	23.00	23.78	23.39
$B_{N30} + F_{N5}$	20.33	20.66	20.50	13.00	13.80	13.40	21.44	21.46	21.45
$B_{N15} + F_{N10}$	21.63	21.60	21.62	16.80	15.86	16.33	23.66	23.33	23.50
$B_{N30} + F_{N10}$	20.33	20.33	20.33	12.40	12.67	12.54	21.40	21.43	21.42
Mean	20.97	21.07		14.27	14.69		22.25	22.35	
C.D. at 5%	BF=N.S., S=N.S., BFxS=N.S.			BF=0.41, S=0.24, BFxS=0.58			BF=0.101, S=0.058, BFxS=0.143		

N.S.= Non-significant

Pertaining to the interaction effect, maximum seed protein content was found in $(B_{N15}+F_{N5}) \times S_2$. The value due to this interaction was, however, at par with that for $(B_{N15}+F_{N10}) \times S_1$ (Table 27). The increase in seed protein content due to $(B_{N15}+F_{N5}) \times S_2$ was 6.35% in comparison with $(B_{N15}+F_W) \times S_1$.

It is evident from the entire data of this experiment that individually; (i) the application of 15 kg N/ha as basal dose and 5 kg N/ha by spray $(B_{N15}+F_{N5})$,

(ii) pre-sowing seed treatment with 0.3 per cent aqueous pyridoxine solution (S_2) and

(iii) the interaction $(B_{N15}+F_{N5}) \times S_2$ in the presence of 30 kg P and 30 kg K/ha proved optimum. Moreover, this should be economically acceptable to the farmers.

4.4 Experiment 4

This experiment was also conducted according to the factorial randomised block design on lentil var.T-36. The treatments consisted of (i) two basal doses of phosphorus, viz., 20 and 30 kg P/ha (B_{P20} and B_{P30}) supplemented with foliar spray of three doses of an aqueous solution of monocalcium superphosphate, i.e., 0 (control), 1 and 2 kg P/ha (F_W, F_{P1} and F_{P2} respectively) at pod filling stage (100d) and (ii) seed soaking in two levels of aqueous pyridoxine solution, viz., 0.2 and 0.3% (S_1 and S_2 respectively).

The parameters were kept the same as in Experiment 1-3. These were studied at 120d (20d after spray) and at harvest to assess the performance of the crop. The data are presented in Table 28-32 and are briefly described below:

4.4.1 Growth characteristics

The data on length, nodule number, fresh weight, dry weight of root, leaf number, NAR, NRA and leaf NPK content are presented in Tables 29-28 and are described below:

4.4.1.1 Root length per plant

The effect of phosphorus treatments, pyridoxine soaking and their interaction was found significant (Table 28).

Regarding phosphorus treatments, maximum length was recorded in the plants receiving (sub-optimal) $B_{P20}+F_{P2}$. However, the value given by this treatment was at par with those for $B_{P30}+F_W$ and $B_{P30}+F_{P1}$. Treatments $B_{P30}+F_{P2}$ and $B_{P20}+F_W$ (showing equal effect) gave the lowest value. Regarding soaking, S_2 gave significantly higher value than S_1.

As far as interaction effect of these treatments was concerned, $(B_{P20}+F_{P2}) \times S_2$ (equalled by $B_{P30}+F_{P1} \times S_2$) gave the maximum value for this parameter. The interaction $(B_{P20}+F_{P2}) \times S_2$ gave an increase of 51.93% in root length as compared with)$B_{P20}+F_W) \times S_1$.

Table 28. Effect of basal and foliar application of phosphorus (B_F) and pre-sowing seed treatment with pyridoxine (S) on root length, root nodule number, fresh and dry weights of root per plant of lentil var.T-36 studied at 120d

(Mean of three replicates)

Basal + Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)											
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Root length (cm)			Root nodule number			Fresh weight of root(g)			Dry weight of root(g)		
$B_{P20} + F_W$	4.66	5.00	4.83	5.23	5.46	5.35	0.113	0.116	0.115	0.076	0.086	0.081
$B_{P30} + F_W$	5.33	5.66	5.50	6.64	6.46	6.55	0.126	0.143	0.135	0.100	0.063	0.082
$B_{P20} + F_{P1}$	5.00	5.66	5.33	5.02	7.14	6.08	0.113	0.150	0.132	0.083	0.116	0.100
$B_{P30} + F_{P1}$	5.33	7.34	6.34	5.66	7.86	6.76	0.133	0.186	0.160	0.100	0.146	0.123
$B_{P20} + F_{P2}$	5.66	7.08	6.37	5.34	7.49	6.42	0.140	0.179	0.160	0.103	0.139	0.121
$B_{P30} + F_{P2}$	3.66	4.33	4.00	4.81	4.63	4.72	0.102	0.106	0.104	0.056	0.063	0.060
Mean	4.94	5.85		5.45	6.51		0.121	0.147		0.086	0.102	
C.D. at 5%	B_F=0.94, S=0.54, B_FxS=1.33			B_F=0.48, S=0.27, B_FxS=0.67			B_F=0.024, S=0.014, B_FxS=0.034			B_F=0.030, S=N.S., B_FxS=0.042		

N.S. = Non-significant

4.4.1.2 Root nodule number per plant

The various phosphorus treatments, pyridoxine soaking and their interaction affected root nodule number significantly (Table 28).

Among various phosphorus treatments, $B_{P20}+F_{P2}$ was found best. It was equalled by $B_{P30}+F_{W}$ and $B_{P30}+F_{P1}$. Regarding soaking treatments, S_2 gave significantly more nodules in comparison with S_1.

Pertaining to the various interactions, $(B_{P20}+F_{P2}) \times S_2$, equalled by $(B_{P30}+F_{P1}) \times S_2$, gave the maximum value. The interaction $(B_{P20}+F_{P2}) \times S_2$ increased root nodule production by 43.21% over $(B_{P20}+F_{W})$.

4.4.1.3 Root fresh weight per plant

The effect of phosphorus application, pyridoxine soaking their interaction was found significant (Table 28).

Regarding phosphorus treatments, $B_{P20}+F_{P2}$ (equalled by $B_{P30}+F_{P1}$) gave the maximum value for fresh weight of root. The plants receiving $B_{P30}+F_{P2}$ and $B_{P20}+F_{W}$ showed equal and lowest value. Among pyridoxine treatments, S_2 gave higher value than S_1.

Among various interactions $(B_{P20}+F_{P2}) \times S_2$, equalled by $(B_{P30}+F_{P1}) \times S_2$, gave the maximum fresh weight of root. The interaction $(B_{P20}+F_{P2}) \times S_2$ produced 58.41% higher root fresh weight compared with $(B_{P20}+F_{W}) \times S_1$.

4.4.1.4 Root dry weight per plant

The effect of different phosphorus treatments and of their interaction with pyridoxine soaking was significant (Table 28).

The treatment $B_{P20}+F_{P2}$ gave maximum value that differed critically from those for the other treatments, except $B_{P20}+F_{P1}$ and $B_{P30}+F_{P1}$. Treatment $B_{P20}+F_W$ (equalled by $B_{P30}+F_W$ and $B_{P30}+F_{P2}$) gave the lowest value. The effect of the two levels of pyridoxine on the dry weight of root showed no significant difference.

Regarding the interactions, $(B_{P20}+F_{P2}) \times S_2$ proved best. However, the value given by this treatment was at par with those for $(B_{P20}+F_{P1}) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$ respectively. The increase due to the interaction $(B_{P20}+F_{P20}) \times S_2$ was 82.89% over $(B_{P20}+F_W) \times S_1$.

4.4.1.5 Leaf number per plant

Effect of phosphorus pyridoxine and their interaction was found significant (Table 29).

The highest number of leaves was recorded in plants receiving $B_{P20}+F_{P2}$ and its value differed critically from those for other phosphorus treatments. Plants receiving $B_{P30}+F_{P2}$ produced the lowest number of leaves. Regarding the soaking treatments, S_2 produced more leaves than S_1.

Table 29. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, net assimilation rate (NAR) and nitrate reductage activity (NRA) of lentil var.T-36 studied at 120d

(Mean of three replicates

Basal+Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Leaf number			NAR($x10^{-4}/cm^2/d$)			NRA(nmol $NO_2^-/g/h$)		
B_{P20} + F_W	45.66	50.00	47.83	1.41	1.45	1.43	54.07	48.66	51.37
B_{P30} + F_W	52.66	69.00	60.83	1.55	1.97	1.76	60.75	73.37	67.06
B_{P20} + F_{P1}	48.67	70.14	59.41	1.86	2.61	2.24	50.96	77.54	64.25
B_{P30} + F_{P1}	57.00	73.23	65.12	1.76	2.89	2.33	67.44	80.36	73.90
B_{P20} + F_{P2}	65.66	72.00	68.83	2.06	2.70	2.38	70.65	80.09	75.37
B_{P30} + F_{P2}	40.66	42.53	41.60	1.09	1.27	1.18	39.44	38.37	38.91
Mean	51.72	62.82		1.62	2.15		57.22	66.40	
C.D. at 5%	BF=2.23, S=1.87, BFxS=4.57			BF=0.177, S=0.012, BFxS=0.250			BF=2.50, S=1.45, BFxS=3.54		

Among various interactions $(B_{P20}+F_{P2}) \times S_2$ proved best for leaf production. However, the value was at par with those for $(B_{P20}+F_{P1}) \times S_2$, $(B_{P30}+F_W) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$. The interaction $(B_{P20}+F_{P2}) \times S_2$ produced 57.69% more leaves than $(B_{P20}+F_W) \times S_1$.

4.4.2 Net assimilation rate (NAR)

Net assimilation rate was computed for 90-120d interval. Thus, the plants had 20d to assimilate the sprayed phosphorus before the final reading at 120d was taken. The effect of phosphorus, pyridoxine, and their interaction on NAR was found to be significant (Table 29).

Application of $B_{P20}+F_{P2}$, showing equal effect with $B_{P20}+F_{P1}$ and $B_{P30}+F_{P1}$, resulted in a higher NAR value in comparison to other phosphorus treatments. Plants receiving $B_{P30}+F_{P2}$ gave the lowest value of NAR. With regard to pyridoxine soaking, S_2 registered higher value than S_1.

Among various interactions, $(B_{P20}+F_{P2}) \times S_2$, showing euqal effect with that of $(B_{P30}+F_{P1}) \times S_2$ gave the maximum value. The interaction $(B_{P20}+F_{P2}) \times S_2$ showed an increase of 91.49% in NAR over $(B_{P20}+F_W) \times S_1$.

4.4.3 Nitrate reductase activity (NRA)

Nitrate reductase activity in leaves was estimated at 120d. Phosphorus, pyridoxine and their interaction all had significant effect on NRA (Table 29).

Regarding phosphorus treatments, $B_{P20}+F_{P2}$ proved best but the value was at par with that for $B_{P30}+F_{P1}$. On the other hand, $B_{P30}+F_{P2}$ gave the lowest value. Regarding the two pyridoxine soaking treatments, S_2 was found to be responsible for higher enzyme activity than S_1.

With regard to the interaction effect, it was noted that $(B_{P20}+F_{P2}) \times S_2$ best but was equalled by $(B_{P20}+F_{P1}) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$. The increase due to $(B_{P20}+F_{P2}) \times S_2$ was 48.12% over $(B_{P20}+F_W) \times S_1$.

4.4.4 Leaf NPK content

Like growth characteristics and NRA, leaf NPK content was also estimated at 120d so that the plants had sufficient time (20d) to assimilate the phosphorus sprayed at 100d growth. NPK content of leaves was affected significantly by the individual and combined application of phosphorus and pyridoxine soaking treatments (Table 30).

4.4.4.1 Nitrogen

Regarding phosphorus treatments, $B_{P20}+F_{P2}$ proved best but the value for leaf N in this treatment was equalled by $B_{P30}+F_{P1}$. Plants receiving $B_{P30}+F_{P2}$ and $B_{P20}+F_W$ gave lowest (equal) value. With regard to pyridoxine soaking treatments, S_2 registered higher leaf N content than S_1 (Table 30).

Table 30. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of lentil var. T-36 studied at 120d

(Mean of three replicates)

Basal+Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
B_{P20} + F_W	1.63	1.81	1.72	0.218	0.266	0.242	2.23	2.48	2.36
B_{P30} + F_W	2.34	2.70	2.52	0.284	0.367	0.326	2.67	3.34	3.01
B_{P20} + F_{P1}	2.33	2.54	2.44	0.245	0.406	0.326	2.27	3.67	2.97
B_{P30} + F_{P1}	2.36	2.76	2.56	0.316	0.409	0.363	2.88	3.79	3.34
B_{P20} + F_{P2}	2.50	2.73	2.62	0.361	0.411	0.386	3.15	3.76	3.46
B_{P30} + F_{P2}	1.86	1.66	1.76	0.208	0.214	0.211	2.18	2.21	2.20
Mean	2.17	2.37		0.272	0.346		2.56	3.21	
C.D. at 5%	BF=0.115, S=0.067, BFxS=0.163			BF=0.009, S=0.005, BFxS=0.014			BF=0.407, S=0.231, BFxS=0.576		

Pertaining to the interaction effect, it was found that $(B_{P20}+F_{P2}) \times S_2$, equalled by $(B_{P30}+F_W) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$ resulted in higher leaf N content in comparison to all other interactions. $(B_{P20}+F_{P2}) \times S_2$ enhanced leaf N content by 67.48% over $(B_{P20}+F_W) \times S_1$.

4.4.4.2 Phosphorus

Application of $B_{P20}+F_{P2}$ proved optimum and its effect differed statistically from those of the remaining treatments. Whereas, $B_{P30}+F_{P2}$ gave significantly lowest value. The seeds soaked in S_2 gave higher value for leaf P content than S_1.

The interaction $(B_{P20}+F_{P2}) \times S_2$ resulted in maximum leaf P content and the value differed critically from all other interactions, except $(B_{P20}+F_{P1}) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$ (Table 30). The interaction $(B_{P20}+F_{P2}) \times S_2$ increased leaf P content by 88.53% in comparison to $(B_{P20}+F_W) \times S_1$.

4.4.4.3 Potassium

Like leaf nitrogen and phosphorus, potassium content of leaves was maximum in $B_{P20}+F_{P2}$. The value given by this treatment was statistically equal to that for $B_{P30}+F_{P1}$, but significantly differed from the values given by all other phosphorus treatments. Plant receiving $B_{P20}+F_W$ (equalled by $B_{P30}+F_{P2}$) showed poorest effect. Soaking of seeds in S_2 gave higher leaf K content compared to S_1.

Regarding the interaction effect, $(B_{P20}+F_{P2}) \times S_2$, equalled by $(B_{P20}+F_{P1}) \times S_2$, $(B_{P30}+F_W) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$ resulted in the higher K content of leaf (Table 30). Increase in leaf potassium content due to $(B_{P20}+F_{P2}) \times S_2$ was 68.61% over $(B_{P20}+F_W) \times S_1$.

4.4.5 Yield characteristics

Five yield parameters (pod number/plant, pod length, seed number/pod, 1,000 seed weight, seed yield) were studied at harvest.

All of these, except the number of seed/pod, were significantly affected by phosphorus and seed soaking alone and in combination (Table 31-32).

4.4.5.1 Pod number per plant

Plant receiving $B_{P20}+F_{P2}$ resulted in maximum production of pods and the value differed critically from those for all other treatments except $B_{P30}+F_{P1}$. Application of $B_{P30}+F_{P2}$ gave the lowest value. Soaking the seeds in the S_2 dose of aqueous pyridoxine solution produced more pods per plant in comparison with S_1.

Regarding the combined effect of phosphorus and pyridoxine, it was revealed that $(B_{P20}+F_{P2}) \times S_2$, equalled by $(B_{P30}+F_{P1}) \times S_2$ produced maximum pods/plant (Table 31). The $(B_{P20}+F_{P2}) \times S_2$ interaction increased the number of pods by 32.00% over $(B_{P20}+F_W) \times S_1$.

Table 31. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of lentil var. T-36
(Mean of three replicates)

Basal+Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Pod number/plant			Pod length (cm)			Seed number/pod		
$B_{P20} + F_W$	107.89	113.22	110.56	0.843	0.940	0.892	1.65	1.80	1.73
$B_{P30} + F_W$	119.44	139.44	129.44	0.950	1.123	1.037	1.81	1.90	1.86
$B_{P20} + F_{P1}$	110.67	136.44	123.56	0.906	1.093	1.000	1.79	1.89	1.84
$B_{P30} + F_{P1}$	127.55	145.89	136.72	0.960	1.183	1.072	1.82	1.91	1.87
$B_{P20} + F_{P2}$	129.67	142.42	136.05	1.023	1.136	1.080	1.88	1.90	1.89
$B_{P30} + F_{P2}$	92.11	103.55	97.83	0.800	0.813	0.807	1.57	1.65	1.61
Mean	114.56	130.16		0.914	1.048		1.75	1.84	
C.D. at 5%	BF=4.37, S=2.52, BFxS=6.18			BF=0.046, S=0.027, BFxS=0.065			BF=N.S., S=0.047, BFxS=N.S.		

N.S.= Non-significant

4.4.5.2 Pod length

Maximum pod length was noted in $B_{P20}+F_{P2}$ but the value given by this treatment was equalled by those recorded in $B_{P30}+F_W$ and $B_{P30}+F_{P1}$. On the other hand, $B_{P30}+F_{P2}$ gave the shortest pods. Soaking the seeds in S_2 produced longer pods than were given by S_1.

The interaction effect of $(B_{P20}+F_{P2}) \times S_2$ was found to be the best, however, the value was at par with those for $(B_{P30}+F_W) \times S_2$ and $(B_{P30}+F_{P1}) \times S_2$ (Table 31). The interaction $(B_{P20}+F_{P2}) \times S_2$ showed 34.76% increase in pod length compared to $(B_{P20}+F_W) \times S_1$.

4.4.5.3 Seed number per pod

As mentioned earlier, application of phosphorus and its interaction with pre-sowing seed treatment with pyridoxine did not affect seed number/pod significantly (Table 31). But pyridoxine treatment alone affected this parameter significantly and S_2 gave critically more seeds per pod in comparison to S_1.

4.4.5.4 1,000 seed weight

Application of $B_{P20}+F_{P2}$ gave maximum value which differed critically from those for all other phosphorus treatments, except $B_{P30}+F_{P1}$. Plant receiving $B_{P30}+F_{P2}$ produced lightest seeds. Regarding the effect of pyridoxine soaking treatments, S_2 proved better and its value differed significantly with that for S_1.

Regarding the interaction effect of phosphorus application and pyridoxine soaking, $(B_{P20}+F_{P2}) \times S_2$, showing equal effect with $(B_{P30}+F_{P1}) \times S_2$, produced the heaviest seeds (Table 32). $(B_{P20}+F_{P2}) \times S_2$ exhibited 4.10% increase in test weight of seed over $(B_{P20}+F_W) \times S_1$.

4.4.5.5 Seed yield

Among various phosphorus applications. $B_{P20}+F_{P2}$ (showing equal effect with $B_{P30}+F_{P1}$) gave maximum seed yield. On the other hand, plants receiving $B_{P30}+F_{P2}$ gave the lowest seed yield. Soaking the seeds in the S_2 dose of pyridoxine gave more seed yield than in S_1.

Pertaining to interaction effect, it was revealed that $(B_{P20}+F_{P2}) \times S_2$, equalled by $(B_{P30}+F_{P2}) \times S_1$, proved best for seed production (Table 32). Application of $(B_{P20}+F_{P2}) \times S_2$ enhanced seed yield by 24.13% in comparison with $(B_{P20}+F_W) \times S_1$.

4.4.6 Seed protein content

The effect of phosphorus, pyridoxine soaking and their interaction on seed protein content was significant (Table 32).

Application of $B_{P20}+F_{P2}$ proved optimum but the value was at par with that for $B_{P30}+F_{P1}$. The application of $B_{P30}+F_{P2}$ and $B_{P20}+F_W$ (having equal effect) gave the lowest value. With regard to soaking treatment, S_2 resulted in more protein content of seeds than S_1.

Table 32. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of lentil var. T-36 (Mean of three replicates)

Basal+Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	1,000 seed weight (g)			Seed yield (q/ha)			Protein content (%)		
$B_{P20} + F_W$	20.72	20.80	20.76	20.43	22.34	21.39	20.48	20.67	20.58
$B_{P30} + F_W$	20.82	21.32	21.07	22.49	24.54	23.52	21.24	22.34	21.79
$B_{P20} + F_{P1}$	20.75	21.27	21.01	21.43	24.38	22.91	20.64	22.31	21.48
$B_{P30} + F_{P1}$	21.09	21.72	21.41	22.97	25.95	24.46	21.68	23.81	22.75
$B_{P20} + F_{P2}$	21.24	21.57	21.41	23.87	25.36	24.62	21.83	23.83	22.83
$B_{P30} + F_{P2}$	20.27	20.67	20.47	17.61	18.51	18.06	20.39	20.27	20.33
Mean	20.82	21.22		21.47	23.51		21.04	22.21	
C.D. at 5%	BF=0.12, S=0.07, BFxS=0.17			BF=0.56, S=0.32, BFxS=0.79			BF=0.61 S=0.35, BFxS=0.86		

Taking interaction effect into consideration, $(B_{P20}+F_{P2}) \times S_2$ proved optimum. However, the value was at par with that for $(B_{P30}+F_{P1}) \times S_2$. $(B_{P20}+F_{P2}) \times S_2$ gave an increase of 16.36% in seed protein content over $(B_{P20}+F_W) \times S_1$.

A perusal of the entire data of this experiment would reveal that:

(i) the application of basal 20 kg P/ha followed by spray of 2 kg P/ha $(B_{P20}+F_{P2})$,

(ii) pre-sowing seed treatment with 0.3 per cent aqueous pyridoxine solution (S_2) and

(iii) the interaction $(B_{P20}+F_{P2}) \times S_2$ together with 30 kg N and 30 kg K/ha proved optimum. These findings are economically sound and are, therefore, expected to be acceptable to the farmers.

4.5 Experiment 5

This was the first field trial on summer moong var.K-851 carried out in 1985. In this factorial randomised field trial, the effects of four basal doses of nitrogen, i.e., 0 kg N/ha (B_{N0}), 5 kg N/ha (B_{N5}), 10 kg N/ha (B_{N10}) and 15 kg N/ha (B_{N15}) and pre-sowing seed treatment with graded aqueous pyridoxine solution, viz., water soaked (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3) alone and in combination on growth characteristics, NAR, leaf NRA, leaf NPK content, yield attributes, seed yield and seed protein content were studied at appropriate stages mentioned under various headings dealing with the data briefly described below (Table 33-38):

4.5.1 Growth characteristics

Five growth parameters, namely, root length, root nodule numbers, root fresh weight, root dry weight and leaf number were studied at 20, 30, 40 and 50d after sowing (Tables 33-35).

4.5.1.1 Root length per plant

The effects of basal nitrogen and pre-sowing seed treatment with pyridoxine alone and of their interaction on root length were found to be significant at all growth stages (Table 33).

Regarding the effect of nitrogen, maximum root length was recorded in the treatment B_{N5}, but its value was at par with that for B_{N10} at all growth stages, except at 30d, when it differed critically from those for all other treatments. Control (B_{N0}) gave poorest effect at each growth stage.

Regarding pyridoxine soaking treatments, S_2 produced the longest roots at all growth stages. However, at 50d, its effect was at par with that of S_1. Control (S_W) showed poorest effect on root length at all growth stages.

When interaction effect was taken into consideration, it was observed that $B_{N5} \times S_1$ gave the maximum root length at

Table 33. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on root length and root nodule number per plant of summer moong var.K-851

(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
										Root length (cm)										
B_{N0}	3.33	4.33	4.66	4.00	4.08	4.33	4.66	5.00	4.33	4.58	6.66	7.00	7.33	7.00	7.00	10.67	12.67	12.67	12.66	12.17
B_{N5}	5.00	5.66	5.66	5.33	5.41	7.00	7.33	8.66	7.00	7.50	7.67	8.33	9.00	7.67	8.17	14.33	15.67	17.33	14.33	15.42
B_{N10}	4.66	5.66	5.66	5.33	5.33	5.33	7.33	7.33	7.20	6.80	7.66	8.33	9.00	8.00	8.25	14.33	15.33	17.00	14.67	15.33
B_{N15}	4.66	4.00	4.66	4.00	4.33	5.00	4.66	7.00	4.33	5.25	7.33	7.00	8.33	6.67	7.33	13.66	14.67	12.67	11.67	13.17
Mean	4.41	4.91	5.16	4.67		5.42	6.00	7.00	5.72		7.33	7.67	8.42	7.34		13.25	14.59	14.92	13.33	
C.D. at 5%	B = 0.13, S = 0.13, BxS = 0.26					B = 0.69, S = 0.69, BxS = 1.37					B = 0.43, S = 0.43, BxS = 0.85					B = 0.95, S = 0.95, BxS = 1.89				
										Root nodule number										
B_{N0}	6.00	7.00	5.78	4.64	5.86	6.33	6.66	6.66	6.60	6.56	7.67	9.33	9.66	8.66	8.83	4.53	5.00	5.33	4.66	4.88
B_{N5}	7.00	8.66	9.00	4.54	7.30	7.66	9.67	12.00	8.66	9.50	10.33	13.33	14.66	11.00	12.33	5.66	8.66	10.33	7.00	8.16
B_{N10}	4.54	6.66	7.46	5.33	6.00	7.66	9.66	11.33	8.68	9.33	10.33	13.33	14.33	12.33	12.50	5.66	8.33	8.67	7.54	7.80
B_{N15}	3.66	8.86	6.42	4.66	5.40	7.00	9.33	6.64	6.33	7.33	10.00	9.00	13.33	8.66	10.25	5.66	4.67	8.00	4.66	5.75
Mean	5.30	7.30	7.17	4.80		7.16	8.83	9.16	7.57		9.58	11.25	12.91	10.16		5.88	6.67	8.08	5.97	
C.D. at 5%	B = 0.63, S = 0.63, BxS = 1.25					B = 1.32, S = 1.32, BxS = 2.64					B = 0.67, S = 0.67, BxS = 1.34					B = 1.03, S = 1.03, BxS = 2.06				

growth stages, except at 20 and 30d, when it was at par with those for $B_{N5} \times S_2$, $B_{N10} \times S_1$ and $B_{N10} \times S_2$ at 40d, with those for $B_{N5} \times S_2$, $B_{N10} \times S_1$, $B_{N10} \times S_2$ and $B_{N15} \times S_2$ and at 50d, with those for $B_{N10} \times S_2$ and $B_{N5} \times S_1$. The interaction $B_{N5} \times S_1$ increased root length by 69.96, 69.28, 25.08 and 46.86% at 20, 30, 40 and 50d respectively over $B_{NO} \times S_W$.

4.5.1.2 Root nodule number per plant

The effect of basal nitrogen and seed soaking, alone and in combination on root nodule number was found to be significant at all growth stages (Table 33).

Regarding the effect of basal nitrogen, B_{N5} proved optimum at all growth stages and its value differed critically from those for all other nitrogen levels at 20d but, at latter stages, it was equal to those for B_{N10}. Control (B_{NO}) showed the poorest response.

As far as the effect of pyridoxine treatment was concerned, S_1 gave maximum value at 20d but its value was at par with that for S_2, whereas, at other stages S_2 produced the highest number of nodules. However, S_2 was at par with S_1, except at 50d, when it critically differed from the rest of the treatments. The control (S_W) gave the lowest value at all the four stages; but it was at par in its effect with one or the other concentration at different stages.

Regarding the interaction effect, B_{N5} x S_2 proved best at all growth stages. However, its value was at par with that for B_{N5} x S_1 at 20d and with B_{N5} x S_1, B_{N10} x S_1 and B_{N10} x S_2, at 30 and 50d. At 40d, one more interaction, i.e., B_{N15} x S_2, showed equal effect with B_{N5} x S_2. Application of B_{N5} x S_1 increased root nodule number by 44.33% at 20d, 52.76% at 30d, 73.79% at 40d and 91.17% at 50d compared with the respective values for B_{N0} x S_W at each stage.

4.5.1.3 Root fresh weight per plant

The effect of basal nitrogen and pyridoxine soaking treatment alone and of their interaction was not found significant for fresh weight of root at any growth stage (Table 34).

4.5.1.4 Root dry weight per plant

The effect of basal nitrogen and pyridoxine soaking treatment alone and of their interaction was found significant at 20, 30 and 40d (Table 34).

Application of B_{N5} gave maximum root dry weight at all growth stages and the value differed significantly from those for all other nitrogen levels at 20d; but at other stages, it was at par with that for B_{N10}. On the other hand, B_{N15} gave lowest value at 20 and 30d, while at 40d, it was at par with the control (B_{N0}).

Regarding soaking treatments, S_2 gave maximum root dry weight at all growth stages and the value differed critically

Table 34. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on fresh and dry weights of root per plant of summer moong var.K-851

(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Fresh weight of root (g)																			
B_{N0}	0.040	0.046	0.040	0.040	0.042	0.190	0.200	0.293	0.243	0.232	0.317	0.660	0.627	0.400	0.501	1.04	1.15	1.07	1.37	1.16
B_{N5}	0.040	0.052	0.066	0.056	0.054	0.173	0.227	0.323	0.227	0.238	0.330	0.742	0.800	0.367	0.560	1.43	1.48	1.54	1.25	1.43
B_{N10}	0.051	0.050	0.060	0.033	0.049	0.250	0.287	0.330	0.210	0.269	0.627	0.722	0.887	0.330	0.642	1.17	1.54	1.50	1.40	1.40
B_{N15}	0.040	0.050	0.034	0.033	0.039	0.220	0.223	0.243	0.200	0.222	0.400	0.667	0.615	0.326	0.502	1.40	1.37	1.34	1.43	1.39
Mean	0.043	0.050	0.050	0.041		0.208	0.234	0.297	0.220		0.419	0.698	0.732	0.356		1.26	1.39	1.36	1.36	
C.D. at 5%	B = N.S., S = N.S., BxS = N.S.					B = N.S., S = N.S., BxS = N.S.					B = N.S., S = N.S., BxS = N.S.					B = N.S., S = N.S., BxS = N.S.				
	Dry weight of root (g)																			
B_{N0}	0.021	0.016	0.032	0.031	0.025	0.107	0.156	0.193	0.123	0.145	0.210	0.283	0.300	0.267	0.265	0.324	0.396	0.407	0.329	0.364
B_{N5}	0.022	0.035	0.035	0.024	0.029	0.147	0.247	0.260	0.117	0.193	0.250	0.330	0.340	0.283	0.301	0.356	0.460	0.470	0.430	0.429
B_{N10}	0.021	0.033	0.032	0.024	0.028	0.147	0.230	0.257	0.157	0.198	0.250	0.321	0.330	0.254	0.289	0.352	0.432	0.460	0.431	0.419
B_{N15}	0.023	0.014	0.026	0.022	0.021	0.117	0.163	0.147	0.114	0.135	0.236	0.268	0.263	0.214	0.245	0.352	0.430	0.432	0.334	0.387
Mean	0.022	0.025	0.031	0.025		0.130	0.199	0.214	0.128		0.237	0.301	0.308	0.255		0.346	0.430	0.442	0.381	
C.D. at 5%	B = 0.0006, S = 0.0006, BxS = 0.0012					B = 0.007, S = 0.007, BxS = 0.014					B = 0.027, S = 0.027, BxS = 0.054					B = N.S., S = N.S., BxS = N.S.				

N.S. = Non-significant

from the rest of the soaking treatments at 20 and 30d; but it was at par with that for S_1 at 40d. The minimum value was given by the control (S_W) at all stages.

Regarding the interaction effect, B_{N5} x S_1 gave maximum dry weight of root at all growth stages. However, it was at par with those for some interactions, including B_{N5} x S_2. The interaction B_{N5} x S_1 showed an increase of 66.67, 130.84 and 57.14% at 20, 30 and 40d respectively over the respective values for B_{N0} x S_W.

4.5.1.5 <u>Leaf number per plant</u>

The effect of basal nitrogen, pyridoxine soaking treatment and their interaction on leaf production was found to be significant at all growth stages (Table 35).

Application of B_{N5} proved optimum but it was equalled by B_{N10} in its effect at all growth stages. Control (B_{N0}) gave poorest effect at all growth stages and the value was equal to those for B_{N15} at 20, 30 and 40d.

Soaking the seeds in S_2 level of pyridoxine proved best for leaf production and the value differed significantly from the rest of the treatment at all growth stages, except at 40d when it was at par with that for S_1. Control (S_W) gave the lowest number of leaves per plant at most of the growth stages.

With regard to the interaction effect, B_{N5} x S_2 proved best. However, it was at par in its effect with B_{N10} x S_2 and

Table 35. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, net assimilation rate (NAR) and nitrate reductase activity (NRA) of summer moong var. K-851

(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean	S_w	S_1	S_2	S_3	Mean
											Leaf number									
B_{NO}	2.78	3.11	3.00	3.78	3.17	10.46	11.33	11.33	10.67	10.95	12.00	15.00	15.00	13.00	13.75	12.67	15.00	15.00	13.00	13.92
B_{N5}	3.67	3.89	4.11	3.67	3.84	12.00	14.00	14.67	12.00	13.17	16.00	19.00	21.00	16.00	18.00	16.00	17.67	19.00	16.00	17.17
B_{N10}	3.56	3.78	3.89	3.67	3.73	12.00	12.67	14.67	12.33	12.92	15.00	18.00	19.00	16.00	17.00	15.00	17.67	18.00	16.33	16.75
B_{N15}	3.33	3.00	3.67	2.89	3.22	11.67	11.00	12.67	10.67	11.50	15.00	16.00	15.00	13.00	14.75	15.00	14.00	17.00	13.00	14.75
Mean	3.34	3.45	3.67	3.50		11.53	12.25	13.34	11.42		14.50	17.00	17.50	14.50		14.67	16.09	17.25	14.58	
C.D. at 5%	B = 0.16, S = 0.16, BxS = 0.32					B = 0.87, S = 0.87, BxS = 1.74					B = 1.05, S = 1.05, BxS = 2.10					B = 0.72, S = 0.72, BxS = 1.44				
											NAR ($x10^{-4}g/cm^2/d$)									
	(20-30d interval)					(30-40d interval)					(40-50d interval)									
B_{NO}	18.24	20.63	23.33	18.82	20.26	9.33	10.20	10.20	9.36	9.77	3.64	4.10	4.16	3.47	3.84					
B_{N5}	23.72	24.87	26.42	24.32	24.83	10.82	13.12	13.20	11.34	12.12	4.60	5.40	5.46	4.63	5.02					
B_{N10}	23.70	24.64	26.22	24.42	24.75	10.62	12.46	13.16	11.36	11.90	4.27	5.37	5.42	5.33	5.10					
B_{N15}	23.43	20.33	24.44	18.66	21.72	10.47	9.37	12.33	9.34	10.38	4.23	3.73	5.35	3.66	4.24					
Mean	22.27	22.62	25.10	21.56		10.31	11.29	12.22	10.35		4.19	4.65	5.10	4.27						
C.D. at 5%	B = 0.64, S = 0.64, BxS = 1.28					B = 0.32, S = 0.32, BxS = 0.64					B = 0.22, S = 0.22, BxS = 0.44									
											NRA (n mol NO_2^-/g/h)									
B_{NO}	140.22	144.72	146.37	114.26	142.14	120.26	122.36	125.82	120.33	122.19	112.13	114.36	114.40	112.69	113.40	101.30	102.20	102.22	101.54	101.82
B_{N5}	150.33	166.00	168.45	150.72	158.88	130.44	136.24	138.46	130.46	133.90	118.82	124.62	126.55	120.30	122.57	106.33	110.37	113.79	106.72	109.30
B_{N10}	148.36	160.37	166.52	152.53	156.92	128.36	134.52	137.33	130.72	132.73	118.06	124.60	126.52	120.36	122.39	105.32	109.84	112.96	108.47	109.15
B_{N15}	146.62	141.77	160.33	140.86	147.40	127.64	120.43	133.27	120.30	125.41	116.48	114.36	122.73	112.18	116.44	102.33	101.73	109.44	101.33	103.71
Mean	146.36	153.22	160.42	146.34		126.68	128.39	133.72	125.45		116.37	119.49	122.55	116.38		103.82	106.04	109.60	104.52	
C.D. at 5%	B = 3.54, S = 3.54, BxS = 7.08					B = 1.75, S = 1.75, BxS = 3.49					B = 1.64, S = 1.64, BxS = 3.28					B = 1.48, S = 1.48, BxS = 2.95				

B_{N5} x S_1 at all growth stages. Moreover, at 50d, its value was statistically equal to that for B_{N10} x S_1 also. The interaction B_{NO} x S_W gave the lowest value at all growth stages. The interaction B_{N5} x S_1 increased leaf number per plant by 39.93, 33.84, 58.33 and 39.46% at 20, 30 and 40 and 50d respectively compared with B_{NO} x S_W.

4.5.2 Net assimilation rate (NAR)

Net assimilation rate was computed for 20-30d, 30-40d and 40-50d intervals. The effect of basal nitrogen and soaking treatment alone and of their interaction was found to be significant at each interval (Table 35).

With regard to basal nitrogen application, B_{N5} proved optimum (but equalled by B_{N10}) at all intervals. The lowest value was given by B_{NO} (control).

Of various doses of pyridoxine, treatment S_2 proved best for NAR at all intervals and its values differed from the rest of the treatments. Control (S_W) and S_3 showed poorest (albeit equal) effect.

Among various interactions, B_{N5} x S_2 (equalled by B_{N10} x S_2) proved best for 20-30d interval. However, at 30-40d values given by the above interactions were at par with that for B_{N5} x S_1 and, at 40-50d, the value for these treatments were statistically equalled by those for some other interactions also.

The interaction effects of B_{N5} x S_1 and B_{N5} x S_2 gave an increase in NAR value of 36.35 and 44.85% at 20-30d; while at 30-40 and 40-50d, the best interaction (B_{N5} x S_1) increased NAR by 40.62 and 48.35% respectively compared with B_{N0} x S_W.

4.5.3 Nitrate reductase activity (NRA)

Nitrate reductase activity was measured in leaves at 20, 30, 40 and 50d. The effect of basal application of nitrogen and pyridoxine alone and their interaction was found significant at all growth stages (Table 35).

Of various basal nitrogen treatments, B_{N5} proved optimum (and equalled by B_{N10}) while the control gave the lowest value at all growth stages.

Regarding pyridoxine soaking, S_2 gave the maximum NRA at all growth stages. The water soaked control (S_W) showed poorest effect and was equalled by S_3 at all growth stages.

Regarding various interactions, B_{N5} x S_1 gave maximum NRA all growth stages; but the value was at par with those for B_{N10} x S_2 and B_{N5} x S_2 at 20, 30 and 40d. Moreover, at 40d B_{N10} x S_1 was also equal in its effect to the above interactions. At 50d, B_{N5} x S_2 and B_{N10} x S_2 proved best (and statistically equal to each other) and B_{N5} x S_1 was found next in order in its effect on NRA. The increase in enzymatic activity due to B_{N5} x S_1 at 20, 30, 40 and 50d over B_{N0} x S_W was 18.39, 13.29, 11.14 and 8.95% respectively.

4.5.4 Leaf NPK content

Leaf NPK content was estimated at 20, 30, 40 and 50d in fully expanded leaves. The effect of basal nitrogen and pyridoxine soaking treatment and their interaction was found to be significant at all growth stages (Table 36).

4.5.4.1 Nitrogen

B_{N5} (equalled by B_{N10}) gave significantly higher value than the other treatments at 20, 30 and 40d. Moreover, at 50d, B_{N10} gave the maximum value. On the other hand, the control (B_{NO}) showed the poorest effect at all growth stages.

Regarding the effect of soaking treatment, maximum leaf nitrogen content was found in S_2 at all growth stages. Control (S_W) and S_3, showing equal effect, had the lower value at all growth stages.

Among the various interactions, B_{N5} x S_2 (showing equal effect with B_{N5} x S_1) gave maximum value at all growth stages. The values given by these two interactions was at par with those for some other interaction also, and differed critically from the rest of the interactions at all growth stages. Control (B_{NO} x S_W) had lowest nitrogen content in leaves at all growth stages. The increase due to B_{N5} x S_1 over B_{NO} x S_W was 26.24, 22.90, 13.69 and 55.65% at 20, 30, 40 and 50d respectively (Table 36).

Table 36. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of summer moong var. K-851

(Mean of three replicates)

Basal treatments (kg N/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
											Nitrogen (%)									
B_{N0}	3.43	3.52	3.54	3.43	3.48	2.62	2.75	2.86	2.53	2.72	2.22	2.24	2.24	2.23	2.23	1.24	1.33	1.34	1.26	1.29
B_{N5}	3.76	4.33	4.43	3.79	4.08	3.12	3.22	3.25	3.16	3.19	2.33	2.53	2.53	2.35	2.44	1.66	1.93	1.95	1.67	1.80
B_{N10}	3.67	4.22	4.34	4.06	4.07	3.11	3.22	3.23	3.21	3.19	2.33	2.48	2.53	2.44	2.45	1.66	1.85	1.93	1.82	1.82
B_{N15}	3.67	3.44	4.22	3.43	3.69	2.87	2.75	3.21	2.53	2.87	2.26	2.23	2.45	2.23	2.29	1.43	1.33	1.84	1.24	1.46
Mean	3.63	3.88	4.13	3.68		2.93	2.98	3.14	2.91		2.29	2.37	2.44	2.31		1.50	1.61	1.77	1.50	
C.D. at 5%	B = 0.12, S = 0.12, BxS = 0.24					B = 0.014, S = 0.014, BxS = 0.028					B = 0.018, S = 0.018, BxS = 0.036					B = 0.017, S = 0.017, BxS = 0.034				
											Phosphorus (%)									
B_{N0}	0.320	0.323	0.324	0.322	0.322	0.252	0.267	0.314	0.253	0.272	0.223	0.227	0.228	0.224	0.226	0.160	0.180	0.180	0.163	0.171
B_{N5}	0.334	0.376	0.396	0.336	0.361	0.322	0.327	0.336	0.323	0.327	0.233	0.250	0.252	0.241	0.244	0.202	0.211	0.214	0.202	0.207
B_{N10}	0.333	0.376	0.374	0.352	0.359	0.321	0.326	0.334	0.324	0.326	0.232	0.246	0.250	0.241	0.242	0.184	0.211	0.212	0.204	0.203
B_{N15}	0.325	0.323	0.354	0.321	0.331	0.316	0.266	0.326	0.252	0.290	0.230	0.225	0.243	0.223	0.230	0.182	0.166	0.208	0.162	0.180
Mean	0.328	0.350	0.362	0.332		0.303	0.297	0.328	0.288		0.230	0.237	0.243	0.237		0.182	0.192	0.204	0.183	
C.D. at 5%	B = 0.011, S = 0.011, BxS = 0.022					B = 0.004, S = 0.004, BxS = 0.008					B = 0.003, S = 0.003, BxS = 0.006					B = 0.002, S = 0.002, BxS = 0.004				
											Potassium (%)									
B_{N0}	3.20	3.34	3.37	3.23	3.29	2.33	2.46	2.50	2.44	2.43	2.23	2.30	2.31	2.26	2.28	1.53	1.80	1.82	1.62	1.69
B_{N5}	3.64	4.22	4.24	4.10	4.05	3.20	3.35	3.41	3.23	3.30	2.45	2.82	2.86	2.45	2.65	1.87	2.21	2.25	1.96	2.07
B_{N10}	3.46	4.16	4.22	4.10	3.99	2.74	3.35	3.38	3.23	3.18	2.36	2.80	2.85	2.62	2.66	1.84	2.20	2.23	1.98	2.06
B_{N15}	3.44	3.32	4.13	3.20	3.52	2.54	2.44	3.32	2.35	2.66	2.33	2.27	2.62	2.24	2.37	1.83	1.80	2.20	1.56	1.85
Mean	3.44	3.76	3.99	3.66		2.70	2.90	3.15	2.81		2.34	2.55	2.66	2.39		1.77	2.00	2.13	1.78	
C.D. at 5%	B = 0.04, S = 0.04, BxS = 0.08					B = 0.05, S = 0.05, BxS = 0.10					B = 0.02, S = 0.02, BxS = 0.04					B = 0.03, S = 0.03, BxS = 0.06				

4.5.4.2 Phosphorus

Considering the effect of nitrogen treatments, the phosphorus content in leaves was maximum in B_{N5} at all growth stages. However, the value given by this treatment was at par with that for B_{N10} at 20, 30 and 40d. Control (B_{NO}) gave the lowest value at all stages, except at 20d, when it was at par with B_{N15}.

Taking the effect of pyridoxine soaking treatment, it was noted that S_2 had maximum phosphorus content in leaves at all growth stages. Water soaked control (S_W) showed poorest effect on leaf phosphorus content at all growth stages.

With regard to interaction effect, B_{N5} x S_2 proved best at all growth stages. However, the value was equal to those for B_{N10} x S_1, B_{N10} x S_2 and B_{N5} x S_1 at 20d; and with those for B_{N10} x S_2, B_{N5} x S_1 and B_{N10} x S_1 at 40 and 50d. At 30d, the effect of B_{N5} x S_2 was at par with that for B_{N10} x S_2. B_{NO} x S_W gave lowest value through out the experiment but was at par with some other interactions at one or the other growth stages. The interaction B_{N5} x S_1 gave an increase of 17.50, 29.76, 12.11 and 31.88% at 20, 30, 40 and 50d respectively over B_{NO} x S_W (Table 36).

4.5.4.3 Potassium

Potassium content of the leaves was maximum in B_{N5} at 20 and 30d. At other stages, B_{N5} and B_{N10} (showing equal effect) gave higher value than those for other levels of applied nitrogen. Control (B_{NO}) gave the lowest value at all growth stages.

With regard to the effect of soaking, S_2 gave maximum potassium content of leaves at all growth stages. The control (S_W) gave the lowest value at all stages, except at 50d, when it was at par with S_3.

Taking interaction effect into consideration, B_{N5} x S_1 (equalled by B_{N5} x S_2 and B_{N10} x S_2) proved best at all growth stages. The value was also at par with those for B_{N10} x S_1 at 20, 30 and 50d and with B_{N15} x S_2 at 30 and 50d. The interaction B_{NO} x S_W showed poorest effect. The interaction B_{N5} x S_1 gave an increase of 31.88, 43.78, 26.44 and 44.44% at 20, 30, 40 and 50d respectively over the respective values for B_{NO} x S_W (Table 36).

4.5.5 Yield characteristics

Five yield parameters, namely pod number/plnt, pod length, seed number/pod, 1,000 seed weight and seed yield, were studied at harvest. The effect of basal nitrogen, pyridoxine soaking treatment and their interaction was significant for all yield parameters, except the interaction effect on 1,000 seed weight. The data are summarised in Tables 37 & 38 and are briefly described below:

4.5.5.1 Pod number per plant

Regarding the effect of basal nitrogen, B_{N5} produced maximum pods and the value was at par with that for B_{N10}. Control (B_{NO}) showed poorest effect, was statistically equalled by the highest dose of nitrogen, i.e. B_{N15} in this detrimental effect.

Among various soaking treatments, S_1 (equalled by S_2) proved best. Water soaked control (S_W) and S_3, being equal, gave the lowest value for the number of pods per plant.

Pertaining to the interaction effect, $B_{N5} \times S_2$ gave maximum value which was at par with that for $B_{N10} \times S_2$. The interaction $B_{N5} \times S_1$ followed in its effect and its value was at par with that for $B_{N10} \times S_2$. The interactions $B_{N5} \times S_2$ and $B_{N5} \times S_1$ increased the production of pods in lentil 94.42 and 55.58% respectively over $B_{NO} \times S_W$ (Table 37).

4.5.5.2 Pod length

Longest pods were obtained by the application of B_{N5} but the value was at par with that for B_{N10}. Control (B_{NO}) had the poorest effect on pod length.

Optimum pod length was recorded in S_2 and the value differed critically from those obtained in the remaining treatments. The water-soaked control (S_W) had poorest effect on pod length and the value was statistically equal to that for S_3.

Table 37. Effect basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of summer moong var. K-851

(Mean of three replicates)

Basal treatments (kg N/ha)	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Pod number/plant					Pod length (cm)					Seed number/pod				
B_{N0}	12.00	14.67	15.00	14.33	14.00	7.87	8.33	8.40	8.20	8.20	10.00	10.66	10.66	10.66	10.50
B_{N5}	16.00	18.67	23.33	16.00	18.50	8.80	9.10	9.20	8.83	8.98	11.00	12.00	12.67	11.00	11.67
B_{N10}	15.33	17.67	20.00	16.33	17.33	8.70	9.03	9.03	8.90	8.92	10.66	12.00	12.33	11.67	11.67
B_{N15}	15.33	16.67	14.67	13.65	15.08	8.53	8.30	9.00	8.03	8.47	10.33	10.33	11.67	10.33	10.67
Mean	14.67	16.92	18.25	15.08		8.48	8.69	8.91	8.49		10.50	11.25	11.83	10.92	
C.D. at 5%	B = 2.18, S = 2.18, BxS = 4.35					B = 0.13, S = 0.13, BxS = 0.26					B = 0.26, S = 0.26, BxS = 0.52				

With regard to the interaction effect, it was noted that $B_{N5} \times S_1$ resulted in maximum pod length. However, the value was statistically equal to those for $B_{N5} \times S_2$, $B_{N10} \times S_1$, $B_{N10} \times S_2$ and $B_{N15} \times S_2$. The increase due to $B_{N5} \times S_1$ was 15.63% over $B_{N0} \times S_W$ (Table 37).

4.5.5.3 Seed number per pod

The maximum seed number was obtained with the application of B_{N5}, the value being statistically equal to that for B_{N10} but showing critical difference with those for the other nitrogen levels. Lowest number of seeds was found in B_{N0} and equalled by B_{N15}.

Among various pyridoxine soaking treatments, S_2 produced significantly maximum number of seeds per pod. On the other hand significant lowest number of seeds was found in water-soaked control (S_W).

As far as interaction effect was concerned, $B_{N5} \times S_2$ gave maximum seeds, however, the value was equal to that for $B_{N10} \times S_2$. Further the value given by the $B_{N10} \times S_2$ was at par with that for $B_{N5} \times S_1$ and $B_{N10} \times S_1$. The interaction $B_{N5} \times S_2$ and $B_{N5} \times S_1$ gave an increase of seed number by 26.7 and 20.0% over $B_{N10} \times S_W$ (Table 37).

4.5.5.4 1,000 seed weight

Among various nitrogen levels, B_{N5} proved optimum and was equalled by B_{N10}. The control (B_{N0}) produced the lightest seeds but its value was at par with that for B_{N15} (Table 38).

Regarding the response to pyridoxine soaking treatment, heaviest seeds were found in S_2. However, its value was at par with that for S_1. Water soaked control (S_W) and S_3 (being equal) produced lighest seeds.

As mentioned earlier, 1,000 seed weight was not affected significantly by the interaction of nitrogen and pyridoxine.

4.5.5.5 Seed yield

As mentioned earlier, the effect of basal nitrogen, pyridoxine soaking as well as their interaction was significant on seed yield (Table 38).

Among various nitrogen levels, B_{N5} gave the maximum seed yield. However, this treatment was at par with B_{N10} in its effect on seed production.Lowest seed yield was recorded in the control (B_{N0}).

Regarding pyridoxine soaking, S_2 proved optimum and the value was critically different from those for the other soaking treatments. Water-soaked control (S_W) gave the poorest yield; but its value was at par with that for S_3.

Regarding the interaction effect, it was observed that $B_{N5} \times S_1$ gave the highest seed yield being at par with $B_{N5} \times S_2$ and $B_{N10} \times S_2$. An increase of 31.72% over $B_{N0} \times S_W$ was noted in $B_{N5} \times S_1$.

Table 38. Effect of basal nitrogen (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of summer moong var. K-851
(Mean of three replicates)

Basal treatments (kg N/ha)	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	1,000 seed weight (g)					Seed yield (q/ha)					Protein content (%)				
B_{N0}	41.27	41.37	41.40	41.33	41.34	8.86	9.30	9.35	9.15	9.17	21.64	21.87	22.06	21.67	21.81
B_{N5}	41.66	42.56	42.63	42.22	42.27	9.88	11.67	12.46	10.33	11.09	22.43	23.34	23.46	22.64	22.97
B_{N10}	41.66	42.50	42.63	42.27	42.27	9.66	10.53	12.15	10.36	10.68	22.33	23.25	23.40	22.83	22.95
B_{N15}	41.64	41.33	42.33	41.27	41.64	9.35	9.22	11.33	9.06	9.74	22.33	21.67	22.83	21.67	22.13
Mean	41.56	41.94	42.25	41.77		9.44	10.18	11.32	9.73		22.18	22.53	22.94	22.20	
C.D. at 5%	B = 0.41, S = 0.41, BxS = N.S.					B = 0.46, S = 0.46, BxS = 0.92					B = 0.16, S = 0.16, BxS = 0.32				

N.S. = Non-significant

4.5.6 Seed protein content

The effect of application of basal nitrogen, pyridoxine soaking treatment and their combinations significantly affected seed protein content (Table 38).

Application of B_{N5} (equalled by the B_{N10}) exhibited the highest protein content of seeds. Control (B_{NO}) gave the lowest value for protein content. The values for both (best and poorest) treatments differed critically with those for the remaining treatments.

With regard to the effect of pyridoxine soaking treatment, the maximum protein content was recorded in S_2. Control (S_W) and S_3, showing equal effect, gave the lowest protein content of seeds.

Regarding the interaction effect, it emerged that $B_{N5} \times S_1$ gave significantly higher protein content than all other interactions, except $B_{N5} \times S_2$, $B_{N10} \times S_2$ and $B_{N10} \times S_1$. The increase due $B_{N5} \times S_1$ was 7.86% in comparison with the effect of the interaction $B_{NO} \times S_W$.

On critically examining the results of this trial, it may be concluded that summer moong seeds should be treated with 0.2% aqueous pyridoxine solution (S_1) for 4h before sowing them with 5 kg N (and 30 kg P and 35 kg K)/ha. This treatment would ensure highest productivity of the crop with best quality seeds. As the technique is simple and inexpensive it should appeal to the growers also.

4.6 Experiment 6

In this factorial randomised field experiment, the effects of four basal doses of phosphorus, viz., 15 kg P/ha (B_{P15}), 30 kg P/ha (B_{P30}), 45 kg P/ha (B_{P45}) and 60 kg P/ha (B_{P60}) and four levels of pre-sowing seed treatments with aqueous pyridoxine solution, i.e., water soaked (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3), alone and of their interaction, on growth characteristics, net assimilation rate (NAR), leaf nitrate reductase activity (NRA), leaf NPK contents, yield attributes including, seed yield and on seed quality judged by seed protein content of summer moong var. K-851 was studies in the field. The data are summarised in Tables 39-44 and are briefly described below.

4.6.1 Growth characteristics

Five growth parameters, i.e., root length/plant, root nodule number/plant, fresh and dry weight of root/plant and leaf number/plant were studied at 20, 30, 40 and 50d after sowing (Tables 39-41).

4.6.1.1 Root length per plant

The effect of varying levels of phosphorus and of soaking of seeds in graded aqueous pyridoxine solution alone as well as of their interaction on root length was significant at all four growth stages (Table 39).

Table 39. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on root length and root nodule number per plant of summer moong var.K-851
(Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Root length (cm)																			
B_{P15}	6.00	7.33	7.83	5.04	6.55	6.66	7.66	7.66	5.66	6.91	6.86	8.66	8.66	6.33	7.63	10.66	12.04	12.33	8.66	10.92
B_{P30}	5.83	7.36	8.33	5.66	6.80	6.33	7.66	8.00	6.66	7.16	6.67	9.69	10.05	6.33	8.19	10.66	12.33	12.66	10.12	11.44
B_{P45}	6.66	7.00	6.33	5.02	6.25	5.33	7.00	6.66	5.66	6.16	7.66	8.33	6.64	5.66	7.07	11.33	12.00	11.13	8.66	10.78
B_{P60}	4.33	6.66	6.04	5.33	5.59	5.33	7.00	6.66	6.00	6.25	5.33	8.08	7.66	5.66	6.68	8.33	11.66	11.21	9.66	10.22
Mean	5.71	7.09	7.13	5.26		5.91	7.33	7.25	6.00		6.63	8.69	8.25	6.00		10.25	12.01	11.83	9.28	
C.D. at 5%	B = 0.49, S = 0.49, BxS = 0.98					B = 0.22, S = 0.22, BxS = 0.43					B = 0.74, S = 0.74, BxS = 1.48					B = 0.43, S = 0.43, BxS = 0.86				
	Root nodule number																			
B_{P15}	6.66	9.33	10.66	5.14	7.95	9.24	12.33	16.66	7.34	11.39	8.16	10.33	12.62	6.06	9.29	5.66	9.33	9.66	4.00	7.16
B_{P30}	6.33	11.66	12.33	5.66	9.00	8.16	12.66	17.33	8.66	11.70	7.23	14.21	14.00	5.33	10.19	5.67	9.67	10.00	5.01	7.59
B_{P45}	7.33	7.33	6.67	5.00	6.58	8.33	10.33	9.00	8.36	9.01	10.17	10.24	8.66	6.45	8.88	7.66	6.33	8.33	4.00	6.58
B_{P60}	4.33	7.33	7.00	5.66	6.08	6.42	9.67	9.33	7.36	8.20	5.00	9.15	10.08	4.66	7.22	3.86	7.66	7.33	5.00	5.96
Mean	6.16	8.91	9.17	5.37		8.04	11.25	13.08	7.93		7.64	10.98	11.34	5.63		5.71	8.25	8.83	4.50	
C.D. at 5%	B = 1.33, S = 1.33, BxS = 2.66					B = 0.62, S = 0.62, BxS = 1.24					B = 1.83, S = 1.83, BxS = 3.66					B = 0.28, S = 0.28, BxS = 0.56				

With regard to the effect of phosphorus, B_{P30} showed maximum root length at all growth stages. However, it was at par with B_{P15} at 20 and 40d but differed critically from the rest of the treatments at 30 and 50d. Application of B_{P60} produced shortest root at all growth stages.

Regarding the effect of soaking treatment, S_1 proved best, but was equalled by S_2, at all growth stages. These two treatments differed critically from the remaining treatments in their effect on root length. On the other hand, water-soaked control (S_W) and S_3, having equal effect, gave lowest value at 20, 30 and 40d. At 50d, only S_3 showed the poorest effect.

Regarding the interaction effect, $B_{P15} \times S_2$ proved best for this parameter at all growth stages. The effect of this interaction at par with those of $B_{P30} \times S_1$ and $B_{P30} \times S_1$ at 20d, $B_{P15} \times S_1$, $B_{P30} \times S_1$ and $B_{P30} \times S_2$ at 30 and 40d, while at 50d, one more treatment $B_{P45} \times S_1$ was also showed equal effect with those for above mentioned interactions. Shortest roots were given by $B_{P60} \times S_W$. Application of $B_{P15} \times S_2$ gave an increased of root length by 30.5% at 20d, 15.02% at 30d, 26.24% at 40d and 15.67% at 50d compared with $B_{P15} \times S_W$ (control).

4.6.1.2 Root nodule number per plant

The effect of phosphorus, pyridoxine soaking treatment and their interaction was significant at all growth stages (Table 39).

Application of B_{P30} resulted in the production of maximum number of root nodules but its value was at par with that for B_{P15} at 30d and with those for B_{P15} and B_{P45} at 40d; treatment B_{P30} showing significant difference from those for other levels at 20 and 50d. The minimum number of nodules was given by B_{P60} at all growth stages.

Regarding the soaking treatment, S_2 produced maximum root nodules at all growth stages. However, it was at par with S_1 at 20 and 40d and differed critically from all soaking treatments at 30 and 50d. S_3 gave the lowest number of nodules per plant at all stages.

When the interaction effect was taken into consideration, B_{P30} x S_2 registered maximum value at 20, 30 and 50d and was equalled by B_{P30} x S_1 and B_{P15} x S_2 at 20 and 50d. However, at 30d, B_{P30} x S_2 was equalled by B_{P15} x S_2 only; whereas, at 40d, maximum number of nodules were recorded in B_{P30} x S_1 and it was equalled by B_{P30} x S_2 and B_{P15} x S_2. The treatment B_{P15} x S_2 gave an increase of 60.06, 80.30, 54.66 and 70.67% at 20, 30, 40 and 50d respectively over B_{P15} x S_W.

4.6.1.3 Root fresh weight per plant

The effect of basally applied phosphorus, pre-sowing seed treatment with pyridoxine solution and their interaction was significant at all growth stages, except at 20d, when the interaction effect was non-significant (Table 40).

Table 40. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on fresh and dry weights of root per plant of summer moong var.K-851
(Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Fresh weight of root (g)																			
B_{P15}	0.050	0.066	0.060	0.033	0.054	0.160	0.223	0.225	0.106	0.179	0.433	0.606	0.703	0.230	0.493	0.903	1.460	1.530	0.711	1.150
B_{P30}	0.046	0.066	0.068	0.040	0.055	0.166	0.236	0.240	0.166	0.202	0.426	0.748	0.776	0.386	0.584	0.906	1.680	1.580	0.863	1.260
B_{P45}	0.056	0.056	0.054	0.033	0.050	0.170	0.200	0.166	0.123	0.165	0.500	0.573	0.470	0.273	0.454	1.060	1.420	0.926	0.735	1.040
B_{P60}	0.033	0.056	0.050	0.033	0.043	0.103	0.190	0.166	0.146	0.151	0.253	0.513	0.490	0.363	0.405	0.703	1.120	1.030	0.817	0.918
Mean	0.046	0.061	0.060	0.035		0.150	0.212	0.199	0.135		0.403	0.610	0.610	0.313		0.893	1.420	1.270	0.782	
C.D. at 5%	B = 0.006, S = 0.006, BxS = N.S.					B = 0.008, S = 0.008, BxS = 0.016					B = 0.077, S = 0.077, BxS = 0.153					B = 0.13, S = 0.13, BxS = 0.26				
	Dry weight of root (g)																			
B_{P15}	0.034	0.043	0.046	0.023	0.037	0.100	0.120	0.133	0.076	0.107	0.160	0.233	0.263	0.133	0.197	0.400	0.520	0.576	0.283	0.445
B_{P30}	0.036	0.056	0.057	0.033	0.046	0.096	0.130	0.146	0.093	0.116	0.130	0.234	0.277	0.123	0.191	0.373	0.563	0.656	0.366	0.490
B_{P45}	0.040	0.043	0.040	0.026	0.037	0.103	0.106	0.100	0.083	0.098	0.163	0.196	0.173	0.140	0.168	0.440	0.480	0.400	0.283	0.401
B_{P60}	0.023	0.040	0.041	0.026	0.033	0.073	0.106	0.101	0.084	0.091	0.166	0.180	0.173	0.120	0.160	0.280	0.460	0.403	0.283	0.357
Mean	0.033	0.046	0.046	0.027		0.093	0.116	0.120	0.084		0.155	0.211	0.222	0.129		0.373	0.506	0.509	0.304	
C.D. at 5%	B = 0.006, S = 0.006, BxS = 0.012					B = 0.007, S = 0.007, BxS = 0.014					B = 0.017, S = 0.017, BxS = 0.034					B = 0.042, S = 0.042, BxS = 0.083				

N.S. = Non-significant

Application of B_{P30} gave maximum value that critically differed at 30 and 40d but was at par with those for B_{P15} and B_{P45} at 20d and for B_{P15} at 50d. On the other hand, B_{P60} gave the lowest value at all growth stages.

Regarding pyridoxine soaking treatment, S_1 registered maximum fresh weight at all growth stages. However, the value was at par with that for S_2 at 20 and 40d, while, at 30 and 50d, it showed significant difference from all remaining treatments. Treatment S_3 showed the poorest effect at all growth stages, except at 50d, when it was equal to the water-soaked control (S_W).

When interaction effect was taken into consideration, it was observed that B_{P15} x S_2 gave maximum fresh weight of root at 30, 40 and 50d. However, the value was at par with those for B_{P30} x S_1 and B_{P30} x S_2 at 30, 40 and 50d. Moreover, at 50d, B_{P15} x S_1 and B_{P45} x S_1 were also equalled by B_{P15} x S_2. The interaction B_{P15} x S_2 increased fresh weight of root by 40.63, 62.36 and 69.44% at 30, 40 and 50d respectively over B_{P15} x S_W.

4.6.1.4 Root dry weight per plant

Individual and combined effect of basal dressing of phosphorus and pyridoxine soaking on the dry weight of root was found to be significant at all growth stages (Table 40).

Regarding the effect of phosphorus, B_{P30} gave the maximum dry weight of root at all growth stages, except at 40d, when it showed equal effect with B_{P15}. On the other hand, B_{P60} gave lowest dry matter of root at all growth stages.

As far as the effect of soaking treatment was concerned, S_2 proved optimum, with S_1 showing equal effect at all growth stages. Treatment S_W and S_3 showing equal effect and gave the lowest dry weight of root at 20d; but at later stages, S_3 showed the minimum value.

Pertaining to the interaction effect, $B_{P30} \times S_2$ was found best (but equalled by $B_{P15} \times S_2$) at all growth stages. Its value was also at par with that for $B_{P30} \times S_1$ at 20d. The interaction $B_{P15} \times S_2$ gave an increase of dry weight of root of 35.29, 30.00, 64.38 and 44.00% at 20, 30, 40 and 50d respectively over the interaction $B_{P15} \times S_W$.

4.6.1.5 <u>Leaf number per plant</u>

The effect of phosphorus, pyridoxine soaking treatment and their interaction on leaf production was found significant at 30, 40 and 50d. At 20d, only individual effect of these treatment was found significant (Table 41).

Basal dressing of phosphorus, B_{P30} gave maximum number of leaves at all growth stages. However, the value given by this treatment was at par with that for B_{P15} at 20, 30 and 40d respectively. Moreover, at 30d, B_{P45} showed equal effect with B_{P30}.

Table 41. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, net assimilation rate (NAR) and nitrate reductase activity (NRA) of summer moong var.K-851

(Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
											Leaf number									
B_{P15}	8.06	9.04	9.00	7.33	8.36	11.66	13.00	14.66	10.00	12.33	13.00	15.00	16.08	13.00	14.27	21.00	28.60	29.50	12.00	22.78
B_{P30}	8.00	9.00	9.00	7.00	8.25	11.33	13.33	15.00	11.00	12.67	13.00	16.60	16.67	13.00	14.82	21.00	29.60	29.23	20.66	25.12
B_{P45}	8.00	8.00	8.00	7.00	7.75	12.00	13.00	12.00	11.00	12.00	15.00	15.00	13.00	13.60	14.15	24.00	25.70	21.60	19.53	22.71
B_{P60}	6.00	8.00	8.00	7.00	7.25	8.66	12.00	12.00	11.00	10.92	12.00	15.00	14.03	13.00	13.51	9.43	24.54	23.62	20.60	19.55
Mean	7.52	8.51	8.50	7.08		10.91	12.83	13.42	10.75		13.25	15.40	14.95	13.15		18.86	27.11	25.99	18.20	
C.D. at 5%	B = 0.54, S = 0.54, BxS = N.S.					B = 0.71, S = 0.71, BxS = 1.42					B = 0.64, S = 0.64, BxS = 1.28					B = 0.62, S = 0.62, BxS = 1.24				
											NAR ($x10^{-4}g/cm^2/d$)									
	(20-30d interval)					(30-40d interval)					(40-50d interval)									
B_{P15}	14.45	22.64	24.39	10.49	17.99	8.64	11.43	11.64	6.73	9.61	2.73	3.62	3.66	2.10	3.03					
B_{P30}	13.37	23.01	24.64	12.73	18.44	8.44	12.33	12.40	8.15	10.33	2.68	3.89	3.90	2.60	3.27					
B_{P45}	20.04	21.90	16.66	11.93	17.63	10.06	10.57	9.32	7.04	9.25	3.43	3.47	2.84	2.40	3.04					
B_{P60}	10.21	20.55	17.18	12.34	15.07	6.32	10.33	9.61	7.73	8.50	2.09	3.34	3.09	2.48	2.75					
Mean	14.52	22.03	20.72	11.87		8.37	11.17	10.74	7.41		2.73	3.58	3.37	2.40						
C.D. at 5%	B = 0.68, S = 0.68, BxS = 1.36					B = 0.58, S = 0.58, BxS = 1.16					B = 0.147, S = 0.147, BxS = 0.294									
											NRA (n mol NO_2^- /g/h)									
B_{P15}	144.45	168.74	170.43	136.28	154.98	126.43	132.34	135.48	120.43	128.67	118.77	125.73	130.05	108.93	120.87	109.67	116.00	120.89	102.04	112.15
B_{P30}	143.37	173.83	174.38	143.44	158.76	124.35	136.83	136.84	122.44	130.12	118.33	127.63	130.10	117.43	123.37	105.53	117.47	121.03	104.05	112.02
B_{P45}	155.47	162.43	149.64	138.56	151.53	129.84	131.63	127.64	121.66	127.69	121.35	125.43	120.16	109.67	119.15	114.33	114.64	109.81	102.34	110.28
B_{P60}	133.89	159.83	150.45	139.66	145.96	120.37	130.46	127.73	122.37	125.23	105.89	124.49	121.35	111.73	115.87	100.64	114.34	110.32	103.04	107.09
Mean	144.29	166.21	161.23	139.49		125.25	132.82	131.92	121.73		116.09	125.82	125.42	111.94		107.54	115.61	115.51	102.87	
C.D. at 5%	B = 2.08, S = 2.08, BxS = 4.16					B = 0.69, S = 0.69, BxS = 1.38					B = 0.58, S = 0.58, BxS = 1.16					B = 1.73, S = 1.73, BxS = 3.46				

N.S. = Non-significant

Regarding soaking treatment, S_1 registered maximum value and was equalled by S_2 at 20, 30 and 40d. While at 50d, the effect of this treatment differed significantly from those for all others soaking treatments. On the other hand, water-soaked control (S_W) and soaking in S_3, showed equal effect and produced minimum leaves at all stages, except at 50d, where S_3 gave the lowest value.

Regarding the interaction effect, $B_{P15} \times S_2$ gave the maximum value and was equalled by $B_{P30} \times S_2$ at 30, 40 and 50d. Moreover, the value was also statistically at par with that for $B_{P30} \times S_1$ at 40d and $B_{P15} \times S_1$ and $B_{P30} \times S_1$ at 50d. The interaction $B_{P15} \times S_2$ showed an increase of 25.73% at 30d, 23.69% at 40d and 40.48% at 50d respectively over $B_{P15} \times S_W$.

4.6.2 Net assimilation rate (NAR)

Net assimilation rate was computed for 20-30, 30-40, and 40-50d intervals and it was significantly affected by phosphorus and pyridoxine treatment alone as well as in combination (Table 41).

Regarding the effect of phosphorus, B_{P30} showed maximum NAR at each interval and its value differed significantly from those for the rest of the treatments, except at 20-30d, when it was equalled by B_{P15}. On the other hand, B_{P60} registered the lowest value.

Maximum NAR was given by S_1, but it was at par with S_2 at 30-40d interval. The highest concentration, viz., S_3 had the lowest value at each interval.

Among the various combinations, $B_{P15} \times S_2$ gave highest value and was equalled by $B_{P30} \times S_2$ at all growth intervals. However, the effect of these treatments was also at par with those for $B_{P15} \times S_1$ and $B_{P30} \times S_1$ at 30-40 and 40-50d intervals. The interaction $B_{P15} \times S_2$ enhanced NAR by 68.79, 34.72, and 34.07% at 20-30, 30-40 and 40-50d intervals in comparison with $B_{P15} \times S_W$.

4.6.3 Nitrate reductase activity (NRA)

Nitrate reductase activity was measured in the leaves at 20, 30, 40 and 50d. Basal application of phosphorus, soaking treatments and interaction had significant effect on activity of this enzyme at all growth stages (Table 41).

Among different basal phosphorus treatments, B_{P30} gave significant higher enzyme activity in comparison to all other phosphorus levels at all stages, except at 50d, when it showed equal effect to that of B_{P15}. Highest basal dose of phosphorus, (B_{P60}) resulted in the lowest NRA at all growth stages.

Among different soaking treatments, S_1 showed the maximum enzyme activity at all stages, except at 40 and 50d, when the value was equal to that for S_2. Highest concentration of pyridoxine soaking, i.e., S_3 gave the lowest NRA at each growth stage.

Of various interactions, B_{P15} x S_2 gave maximum activity; but the value was equalled by B_{P30} x S_2 at all growth stages. Moreover, at 20 and 30d, B_{P30} x S_1 was also equalled the above interactions. The increase in NRA due to B_{P15} x S_2 at 20, 30, 40 and 50d over B_{P15} x S_W was 17.99, 7.16, 9.50 and 10.23% respectively.

4.6.4 Leaf NPK content

Leaf NPK content was estimated at 20, 30, 40 and 50d in fully expanded leaves. The effect of basal dressing of phosphorus, pyridoxine soaking and their interaction on leaf NPK content was significant at all growth stages. The data are summarised in Table 42 and are briefly described below:

4.6.4.1 Nitrogen

Nitrogen content of leaves was maximum in B_{P30} at all growth stages. The value given by this treatment differed critically from those of the rest of the treatments at 30d; but was at par with that for B_{P45} at 20d. Moreover, at 40 and 50d, B_{P15} was also equalled by the above treatments. The highest basal dose (B_{P60}) resulted in the lowest leaf nitrogen content at all stages, except at 20 and 30d, when the value was at par with that for B_{P15}.

Regarding the effect of pyridoxine soaking treatment, S_2 had maximum value at all growth stages, except at 50d, when soaking in S_1 proved best. The value given by S_2 was at

Table 42. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of summer moong var.K-851

(Mean of three replicates)

Basal treatments (kg P/ha)	Sampling stages (days after sowing)																			
	20					30					40					50				
	Soaking treatments (% pyridoxine)																			
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
											Nitrogen (%)									
B_{P15}	3.50	3.53	3.77	3.16	3.49	2.66	2.52	3.02	2.44	2.66	2.24	2.42	2.61	2.33	2.40	1.38	1.81	1.86	1.21	1.57
B_{P30}	3.34	3.83	3.89	3.25	3.58	2.80	3.01	3.05	2.78	2.91	2.34	2.54	2.64	2.18	2.43	1.34	1.81	1.88	1.24	1.57
B_{P45}	3.68	3.75	3.56	3.22	3.55	2.74	2.89	3.00	2.56	2.80	2.27	2.37	2.52	2.41	2.39	1.66	1.77	1.57	1.27	1.57
B_{P60}	3.13	3.64	3.70	3.20	3.42	2.40	2.86	2.83	2.33	2.61	2.12	2.31	2.23	2.15	2.20	1.19	1.77	1.60	1.27	1.46
Mean	3.41	3.69	3.73	3.21		2.65	2.82	2.98	2.53		2.24	2.41	2.50	2.27		1.39	1.79	1.73	1.25	
C.D. at 5%	B = 0.075, S = 0.075, BxS = 0.150					B = 0.073, S = 0.073, BxS = 0.146					B = 0.061, S = 0.061, BxS = 0.122					B = 0.045, S = 0.045, BxS = 0.089				
											Phosphorus (%)									
B_{P15}	0.341	0.381	0.384	0.310	0.354	0.265	0.298	0.300	0.228	0.273	0.225	0.243	0.247	0.211	0.232	0.173	0.197	0.200	0.133	0.176
B_{P30}	0.336	0.388	0.394	0.331	0.362	0.257	0.301	0.303	0.254	0.279	0.225	0.251	0.254	0.220	0.238	0.166	0.202	0.211	0.160	0.185
B_{P45}	0.364	0.377	0.343	0.321	0.350	0.278	0.294	0.273	0.234	0.270	0.233	0.241	0.231	0.215	0.230	0.185	0.193	0.179	0.135	0.173
B_{P60}	0.306	0.376	0.345	0.327	0.339	0.211	0.287	0.275	0.243	0.254	0.210	0.237	0.233	0.219	0.225	0.121	0.189	0.183	0.158	0.163
Mean	0.337	0.379	0.367	0.322		0.253	0.295	0.288	0.240		0.223	0.243	0.241	0.216		0.161	0.195	0.193	0.147	
C.D. at 5%	B = 0.006, S = 0.006, BxS = 0.012					B = 0.002, S = 0.002, BxS = 0.004					B = 0.004, S = 0.004, BxS = 0.008					B = 0.006, S = 0.006, BxS = 0.013				
											Potassium (%)									
B_{P15}	4.65	4.98	5.00	4.33	4.74	3.61	3.88	3.92	3.24	3.66	2.61	2.96	3.00	2.35	2.73	1.44	1.98	2.00	1.13	1.64
B_{P30}	4.61	5.00	5.03	4.60	4.81	3.57	4.01	4.11	3.52	3.80	2.53	3.08	3.11	2.52	2.81	1.40	2.11	2.13	1.32	1.74
B_{P45}	4.83	4.93	4.73	4.44	4.73	3.79	3.84	3.69	3.25	3.64	2.71	2.87	2.64	2.40	2.66	1.65	1.88	1.46	1.23	1.56
B_{P60}	4.15	4.83	4.76	4.55	4.57	3.21	3.80	3.71	3.43	3.54	2.33	2.74	2.69	2.44	2.55	1.12	1.83	1.56	1.23	1.44
Mean	4.56	4.94	4.88	4.48		3.55	3.88	3.86	3.36		2.55	2.91	2.86	2.43		1.40	1.95	1.79	1.23	
C.D. at 5%	B = 0.07, S = 0.07, BxS = 0.14					B = 0.15, S = 0.15, BxS = 0.30					B = 0.073, S = 0.073, BxS = 0.146					B = 0.08, S = 0.08, BxS = 0.16				

par with that for S_1 at 20d. The highest concentration of pyridoxine treatment, i.e., S_3 resulted in the lowest accumulation of leaf nitrogen content, except at 40d, when its value was at par with that for S_W (control).

Regarding interaction effect, B_{P15} x S_2 gave maximum leaf nitrogen content; but it was equalled by B_{P30} x S_2, B_{P30} x S_1 and B_{P45} x S_1 at 20d; B_{P15} x S_2, B_{P30} x S_1 and B_{P45} x S_2 at 30 and 40d and B_{P15} x S_2, B_{P15} x S_1 and B_{P30} x S_1 at 50d (Table 42). The interaction effect of B_{P15} and S_2 showed an increase in leaf nitrogen content of 7.71, 13.53, 16.52, and 34.78% at 20, 30, 40 and 50d respectively over B_{P15} x S_W.

4.6.4.2 Phosphorus

Considering the effect of phosphorus at all the four stages, the phosphorus percentage of leaves was maximum in B_{P30}. The highest dose, i.e., B_{P60} resulted in significantly lowest phosphorus content in leaves at all stages.

Taking the effect of soaking treatment into consideration, phosphorus content in leaf was found to be maximum in S_1 at all growth stages. The value given by this treatment differed significantly from those for all other treatments at each stage, except at 40 and 50d, when it was at par with that for S_2. S_3 gave the lowest phosphorus content of leaves at each growth stages.

Among various interactions, B_{P15} x S_2 gave maximum leaf phosphorus content and its value differed critically from those for all other interactions, except those for B_{P30} x S_1 and B_{P30} x S_2 at all growth stages (Table 42). The interaction B_{P15} x S_2 enhanced leaf phosphorus content by 12.28, 13.21, 8.78 and 15.61% at 20, 30, 40 and 50d respectively over B_{P15} x S_W.

4.6.4.3 Potassium

Maximum potassium content of leaves was recorded in the plants receiving B_{P30} at all growth stages. However, the value given by this treatment was at par with that for B_{P15} at 20 and 30d. Treatment B_{P60} gave the lowest potassium content at all stages.

With regard to the effect of pyridoxine soaking, S_1 gave maximum value at all growth stages. However, the value was equalled by S_2 at 20, 30 and 40d. On the other hand S_3 gave the lowest potassium content of leaves at all stages.

Regarding the interaction effect, B_{P15} x S_2 registered maximum value and was equalled by B_{P15} x S_1, B_{P30} x S_1 and B_{P30} x S_2 at all stages. Moreover, at 20 and 30d, B_{P45} x S_1 was also statistically equal to B_{P15} x S_2 (Table 42). The interaction B_{P15} x S_2 gave an increase in leaf potassium content of 7.53, 8.59, 14.94 and 38.89% at 20, 30, 40 and 50d respectively over B_{P15} x S_W.

4.6.5 Yield characteristics

Five yield characters, namely, pod number/plant, pod length, seed number/pod, 1,000 seed weight and seed yield, were studied at harvest. The effect of basal dressing of phosphorus, soaking the seeds in pyridoxine, and their interaction was significant on all yield parameters, except interaction effect on 1,000 seed weight. The data are summarized in Table 43-44 and are described below in brief.

4.6.5.1 Pod number per plant

With regard to the phosphorus effect, B_{P30} and B_{P15} (having equal effect) gave more pods than those given by other phosphorus level. B_{P60} resulted in the lowest number of pods.

Of various pyridoxine soaking treatment, S_1 proved optimum but was equalled by S_2. Treatment S_3 gave the lowest value.

Among the various interactions, B_{P15} x S_2 and B_{P30} x S_2 (showing equal effect) produced maximum number of pods (Table 43). The interaction B_{P15} x S_2 enhanced pod number by 23.08% over B_{P15} x S_W.

4.6.5.2 Pod length

Significant longest and shortest pods were found in B_{P30} and B_{P60} respectively.

Table 43. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of summer moong var P-651

(Mean of three replicates)

Basal treatments (kg P/ha)	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	Pod number/plant					Pod length (cm)					Seed number/pod				
B_{P15}	13.00	15.33	16.00	12.00	14.08	6.62	7.18	7.33	5.99	6.78	8.00	8.50	8.53	7.14	8.04
B_{P30}	12.66	15.33	16.00	12.66	14.16	6.60	7.56	7.59	6.37	7.03	8.00	8.75	8.78	8.00	8.38
B_{P45}	14.33	15.00	13.66	12.66	13.91	6.93	7.06	6.60	6.43	6.67	8.25	8.50	8.35	7.25	8.09
B_{P60}	11.66	14.66	14.00	12.33	13.16	5.92	6.98	6.62	6.48	6.50	7.12	8.25	8.25	7.25	7.72
Mean	12.91	15.08	14.92	12.41		6.52	7.20	7.04	6.32		7.84	8.50	8.48	7.41	
C.D. at 5%	B = 0.24, S = 0.24, BxS = 0.48					B = 0.24, S = 0.24, BxS = 0.48					B = 0.13, S = 0.13, BxS = 0.26				

Regarding pyridoxine soaking treatment, S_1 gave maximum value. However, it was at par with that for S_2. The poorest effect was noted in the treatment S_3 but the value was statistically equal to that for S_W (water-soaked control).

With regard to the interaction effect, $B_{P15} \times S_2$ gave maximum pod length. However, the value was at par with those for $B_{P15} \times S_1$, $B_{P30} \times S_1$ and $B_{P30} \times S_2$ (Table 43). The combined dose of B_{P15} and S_2 gave an increase in pod length of 10.73% over $B_{P15} \times S_W$.

4.6.5.3 Seed number per pod

The maximum seed number was noted in B_{P30}. On the other hand, the lowest number of seeds per pod was recorded in B_{P60}.

Among the soaking treatment, S_1 proved optimum. However, it was equalled by S_2. The lowest seed number was recorded in S_3.

Among various interactions, application of $B_{P15} \times S_2$ gave maximum value which was at par with those for $B_{P30} \times S_1$ and $B_{P30} \times S_2$ (Table 43). The interaction $B_{P15} \times S_2$ showed an increase of 4.38% over $B_{P15} \times S_W$.

4.6.5.4 1,000 seed weight

The effect of phosphorus application and of soaking the seeds in aqueous pyridoxine solution alone was significant for test weight (Table 44). Among various phosphorus levels, B_{P15} proved best, but the value was at par with that for B_{P30}. Application of B_{P60} produced lightest seeds. However, the value was equalled by B_{P45}.

Regarding pyridoxine treatment, S_2 proved best but was equalled by S_1. The highest concentration, i.e., S_3 produced lightest seed and the value given by this treatment was statistically equalled by the water-soaked control (S_W).

4.6.5.5 Seed yield

As mentioned earlier (p.177),the effect of phosphorus, soaking treatment as well as their interaction was found to be significant on seed yield (Table 44).

Among the various phosphorus treatments, B_{P30} proved best. The values given by various levels of phosphorus significantly differed from each other. The lowest seed yield was recorded in plants receiving B_{P60}.

Regarding the pyridoxine soaking treatment, S_2 gave maximum seed yield. The value given by different pyridoxine soaking treatments showed significant difference from each other. The highest concentration of pyridoxine soaking, i.e., S_3, resulted in lowest seed yield.

Taking the interaction effect of phosphorus and soaking treatment, into consideration, $B_{P15} \times S_2$ gave maximum seed yield.

Table 44. Effect of basal phosphorus (B) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of summer moong var. K-851

(Mean of three replicates)

Basal treatments (kg P/ha)	Soaking treatments (% pyridoxine)														
	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean	S_W	S_1	S_2	S_3	Mean
	1,000 seed weight (g)					Seed yield (q/ha)					Protein content (%)				
B_{P15}	42.40	41.82	42.91	42.49	42.41	8.34	8.50	10.93	6.55	8.58	21.03	21.80	23.50	19.20	21.38
B_{P30}	42.34	41.98	42.99	41.53	42.21	8.17	10.22	11.34	7.80	9.38	19.80	20.03	23.90	20.50	21.06
B_{P45}	40.32	42.49	42.67	40.32	41.47	9.24	9.80	10.40	6.82	9.07	22.00	21.17	18.50	18.66	20.08
B_{P60}	40.98	42.49	42.49	40.47	41.61	6.20	9.50	8.64	7.50	7.96	18.50	21.30	20.80	18.61	19.80
Mean	41.51	42.20	42.79	41.20		7.99	9.51	10.33	7.17		20.33	21.08	21.68	19.24	
C.D. at 5%	B = 0.63, S = 0.63, BxS = N.S.					B = 0.26, S = 0.26, BxS = 0.51					B = 0.32, S = 0.32, BxS = 0.64				

N.S. = Non-significant

However, the value given by this treatment was at par with that for $B_{P30} \times S_2$. An increase of 31.06% over $B_{P15} \times S_W$ was noted due to $B_{P15} \times S_2$.

4.6.6 Seed protein content

It is evident from Table 44 that maximum seed protein content was given by treatment B_{P15} which was, however, equalled by B_{P30}. Treatment B_{P60} gave the lowest value for seed protein content. However, the value was at par with that for the water-soaked control (S_W).

Regarding soaking treatment, S_2 gave the maximum seed protein content. The highest concentration of pyridoxine, i.e., S_3, had significant lowest effect.

Regarding the interaction effect, it emerged that $B_{P15} \times S_2$ and $B_{P30} \times S_2$ (showing equal effect) gave the highest seed protein content. The increase due to $B_{P15} \times S_2$ over $B_{P15} \times S_W$ was 11.75%.

The overall conclusion of this field experiment is that application of 15 kg P (together with 10 kg N and 35 kg K/ha uniformly at the time of sowing) and soaking of seed in 0.3 per cent aqueous pyridoxine solution should ensure high returns to the farmer with minimum investment by way of inputs and technology.

4.7 Experiment 7

In this factorial randomised field experiment, the effect of basal and foliar nitrogen application, pyridoxine soaking and their interaction was studied on growth and yield performance of summer moong var. K-851 (Tables 45-50). The scheme of the treatments is given in Table 8.

4.7.1 Growth characteristics

Five growth characteristics, namely, root length, root nodule number, root fresh weight, root dry weight and leaf number, were studied at 40 and 50d after sowing. All of these parameters were significantly affected by nitrogen treatments, except root nodule number at 50d. However, the effect of pyridoxine soaking treatment was significant for root length, and root nodule number at 40d and for leaf number at both growth stages (40 and 50d). However, their interaction effect was significant for all of these growth characteristics at both stages, except root nodule number at 50d (Tables 45-47).

4.7.1.1 Root length per plant

Regarding nitrogen treatment, application of $B_{N2.5}+F_{N1.25}$ gave maximum root length both at 40 and 50d. On the other hand, application of $B_{N2.5}+F_W$ resulted in the lowest value at both stages. Regarding the soaking treatment, S_2 gave higher value than S_1 at 40d, whereas, at 50d soaking in aqueous pyridoxine solution had an effect that was at par with the performance of the S_1.

Table 45. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on root length and root nodule number per plant of summer moong var.K-851 (Mean of three replicates)

Basal + foliar treatments (kg N/ha)	Sampling stages (days after sowing)											
	40			50			40			50		
	Soaking treatments (% pyridoxine)											
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Root length (cm)						Root nodule number					
$B_{N2.5} + F_W$	9.67	9.67	9.67	14.00	14.00	14.00	7.00	7.33	7.17	5.33	5.33	5.33
$B_{N5} + F_W$	10.00	10.00	10.00	14.00	14.33	14.17	7.33	8.66	8.00	5.66	6.33	6.00
$B_{N2.5} + F_{N1.25}$	12.67	15.00	13.84	17.00	18.33	17.67	10.00	10.33	10.17	7.33	7.66	7.50
$B_{N2.5} + F_{N2.5}$	11.33	14.33	12.83	17.00	16.67	16.84	10.00	9.33	9.67	7.54	7.06	7.30
$B_{N2.5} + F_{N5}$	10.67	10.67	10.67	15.33	14.67	15.00	8.66	9.33	9.00	7.00	6.66	6.83
Mean	10.87	11.93		15.47	15.60		8.60	9.00		6.57	6.61	
C.D. at 5%	BF=0.33, S=0.21, BFxS=0.47			BF=0.61, S=N.S., BFxS=0.86			BF=0.41, S=0.26, BFxS=0.58			BF=N.S., S=N.S., BFxS=N.S.		

N.S. = Non-significant

Regarding the interaction effect of nitrogen and soaking treatment, it emerged that root length was more in the plants receiving $(B_{N2.5} + F_{N1.25}) \times S_2$ at both stages (Table 45). This treatment showed an increase of 55.12 and 30.93% over $(B_{N2.5} + F_W) \times S_1$ at 40 and 50d respectively.

4.7.1.2 Root nodule number per plant

The effect of nitrogen application, soaking treatments and their interaction had significant effect on this parameter at 40d only (Table 45). Treatment $B_{N2.5} + F_{N1.25}$ gave the maximum value. All nitrogen treatment showed significant difference from each other in their effect. The lowest number of nodules was noted in $B_{N2.5} + F_W$. Regarding soaking treatment, S_2 produced more root nodules in comparison to S_1.

Among the various interactions, $(B_{N2.5} + F_{N1.25}) \times S_2$ proved optimum and its value differed critically from those for the other interaction, except $(B_{N2.5} + F_{N1.25}) \times S_1$ and $(B_{N2.5} + F_{N2.5}) \times S_1$. The interaction $(B_{N2.5} + F_{N1.25}) \times S_2$ increased root nodule number per plant by 47.57% over $(B_{N2.5} + F_W) \times S_1$.

4.7.1.3 Root fresh weight per plant

Data from Table 46 showed that maximum fresh weight of root was produced by the plants receiving $B_{N2.5} + F_{N1.25}$. The value given by this treatment significantly differed from those for all other treatments at both stages, except at 50d, when

Table 46. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on fresh and dry weights of root per plant of summer moong var.K-851 (Mean of three replicates)

Basal + foliar treatments (kg N/ha)	Sampling stages (days after sowing)											
	40			50			40			50		
	Soaking treatments (% pyridoxine)											
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Fresh weight of root (g)						Dry weight of root (g)					
$B_{N2.5} + F_W$	0.613	0.613	0.613	1.29	1.33	1.31	0.176	0.203	0.190	0.422	0.422	0.422
$B_{N5} + F_W$	0.626	0.660	0.643	1.38	1.38	1.38	0.223	0.247	0.235	0.423	0.460	0.442
$B_{N2.5} + F_{N1.25}$	0.880	0.950	0.915	1.60	1.70	1.65	0.327	0.347	0.337	0.533	0.580	0.557
$B_{N2.5} + F_{N2.5}$	0.930	0.770	0.850	1.67	1.50	1.59	0.333	0.293	0.313	0.516	0.530	0.523
$B_{N2.5} + F_{N5}$	0.750	0.700	0.725	1.48	1.44	1.46	0.280	0.270	0.275	0.522	0.468	0.495
Mean	0.760	0.739		1.48	1.47		0.270	0.272		0.483	0.492	
C.D. at 5%	BF=0.045, S=N.S., BFxS=0.063			BF=0.092, S=N.S., BFxS=0.130			BF=0.018, S=N.S., BFxS=0.026			BF=0.031, S=N.S., BFxS=0.044		

N.S.= Non-significant

it was equal to that for $B_{N2.5}$ + $F_{N2.5}$. On the other hand, the control ($B_{N2.5}$+ F_W) gave the lowest value at both stages. However, soaking resulted in equal effect of both levels of pyridoxine.

Regarding the interaction effect of nitrogen and pyridoxine soaking treatments, it was found that ($B_{N2.5}$+$F_{N1.25}$)xS_2 produced maximum fresh weight at both stages and the value differed significantly from those for all other interactions, except, at 40d when it was equal to that for ($B_{N2.5}$+$F_{N2.5}$) x S_1 and at 50d to those for ($B_{N2.5}$+$F_{N1.25}$) x S_1 and ($B_{N2.5}$+$F_{N2.5}$) x S_1. The interaction ($B_{N2.5}$+$F_{N1.25}$) x S_2 gave an increase of 54.98 and 31.78% at 40 and 50d respectively over ($B_{N2.5}$+F_W) x S_1.

4.7.1.4 Root dry weight per plant

It is evident from Table 46 that, at both sampling stages, $B_{N2.5}$+$F_{N1.25}$ produced significantly maximum root dry weight. Control ($B_{N2.5}$+F_W) gave lowest value at each growth stage. The effect of pyridoxine soaking treatments (S_1 and S_W) was non-significant at 40 as well as 50d.

Regarding the interaction effects, maximum dry matter was noted to be produced in the interaction ($B_{N2.5}$+$F_{N1.25}$) x S_2 at both stages, and the value differed significantly from those for other interactions at 50d, whereas at 40d, it was at par with those for ($B_{N2.5}$+$F_{N1.25}$) x S_1 and ($B_{N2.5}$+$F_{N2.5}$) x S_1 and differed from those of the remaining interactions. The increase due to $(B_{N2.5}+F_{N1.25}) \times S_2$ over $(B_{N2.5}+F_W) \times S_1$ was 97.16 and 37.44% at 40 and 50d respectively.

4.7.1.5 Leaf number per plant

The effect of nitrogen application, pyridoxine soaking treatments and their interaction was found to be significant at all stages (Table 47).

Treatment $B_{N2.5}+F_{N1.25}$ prodcued maximum leaves at both growth stages, except that at 50d, the value was at par with that for $B_{N2.5}+F_{N2.5}$. Control $(F_{N2.5}+F_W)$ gave the lowest value at both stages, except, at 50d, when it was equalled by $B_{N5}+F_W$. Soaking the seeds in S_2 produced significantly more leaves that doing so in S_1 at 40 as well as 50d.

Considering the various interactions, it emerged that $(B_{N2.5}+F_{N1.25}) \times S_2$ produced maximum leaves and the value differed significantly from those for the rest of the treatment at both stages, except at 50d, when it was at par with that for $(B_{N2.5}+F_{N2.5}) \times S_2$. The combined effect of $(B_{N2.5}+F_{N1.25}) \times S_2$ enhanced leaf number by 90.91 and 42.86% at 40 and 50d over the effect of $(B_{N2.5}+F_W) \times S_1$.

4.7.2 Net assimilation rate (NAR)

Net assimilation rate was computed for 30-40d and 40-50d intervals to assess the individual and combined effect of

Table 47. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, net assimilation rate (NAR) and nitrate reductase activity (NRA) on summer moong var.K-851

(Mean of three replicates)

Basal + foliar treatments (kg N/ha	Sampling stages (days after sowing)																	
	40			50									40			50		
	Soaking treatments (% pyridoxine)																	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Leaf number						NAR ($\times 10^{-4}$ g/cm^2/d) (30-40d interval)			NAR ($\times 10^{-4}$ g/cm^2/d) (40-50d interval)			NRA (n mol NO_2^- /g/h)					
$B_{N2.5}$ + F_W	11.00	14.00	12.50	14.00	14.00	14.00	12.40	12.46	12.43	4.66	4.66	4.66	118.78	120.45	119.62	94.52	96.57	95.55
B_{N5} + F_W	14.00	15.00	14.50	14.00	14.00	14.00	12.64	13.42	13.03	5.20	5.36	5.28	122.39	124.52	123.46	100.62	100.62	100.62
$B_{N2.5}$ + $F_{N1.25}$	17.00	21.00	19.00	19.00	20.00	19.50	14.20	14.57	14.39	6.20	6.34	6.27	130.53	135.69	133.11	108.66	117.36	113.01
$B_{N2.5}$ + $F_{N2.5}$	18.00	17.00	17.50	19.00	19.67	19.34	13.67	14.23	13.95	5.73	6.26	6.00	133.43	130.30	131.87	110.57	104.38	107.48
$B_{N2.5}$ + F_{N5}	17.00	15.00	16.00	16.00	16.00	16.00	13.63	13.60	13.62	5.47	5.70	5.59	129.72	126.63	128.18	100.82	104.22	102.56
Mean	15.20	16.40		16.40	16.73		13.31	13.66		5.45	5.66		126.97	127.52		103.04	104.63	
C.D. at 5%	BF=0.76, S=0.48, BFxS=1.08			BF=0.40, S=0.25, BFxS=0.57			BF=0.41, S=0.26, BFxS=0.58			BF=0.24, S=0.15, BFxS=0.34			BF=0.81, S=0.51, BFxS=1.14			BF=1.64, S=1.04, BFxS=2.32		

nitrogen and pyridoxine soaking treatments. It was found that the effects of nitrogen application, soaking treatments and their interactions were significant at each growth interval (Table 47).

Regarding the effect of nitrogen application, $B_{N2.5}+F_{N1.25}$ gave the maximum value for NAR at both intervals. On the other hand, the lowest value for NAR was noted in the control ($B_{N2.5}+F_{W}$). Soaking treatment S_2 registered a higher value than S_1.

Among various interactions, $(B_{N2.5}+F_{N1.25}) \times S_2$ proved best at each of the two interval. However, the value was at par with those for $(B_{N2.5}+F_{N1.25}) \times S_1$ and $(B_{N2.5}+F_{N2.5}) \times S_2$ at both intervals. The interaction $(B_{N2.5}+F_{N1.25}) \times S_2$ enhanced NAR by 17.50 and 36.05% at 30-40 and 40-50d intervals respectively over $(B_{N2.5}+F_{W}) \times S_1$.

4.7.3 Nitrate reductase activity (NRA)

Nitrate reductase activity was estimated in leaves at 40 and 50d and the effect of nitrogen, pyridoxine soaking treatments and their interactions was found to be significant (Table 47).

Among nitrogen treatments, $B_{N2.5}+F_{N1.25}$ gave maximum leaf NRA at both stages and the values differed significantly from each other. Control, i.e., $B_{N2.5}+F_{W}$, showed the lowest enzyme activity. Soaking the seeds in S_2 level of aqueous pyridoxine solution gave significantly more enzyme activity in comparison to S_1 at both stages.

Among the various interactions, $(B_{N2.5}+F_{N1.25}) \times S_2$ resulted in maximum enzyme activity at both stages, increasing the enzyme activity by 13.24 and 24.16% at 40 and 50d respectively over $(B_{N2.5}+F_W) \times S_1$.

4.7.4 Leaf NPK content

These elements were estimated in fully expanded leaves and were found to be significantly affected by individual and combined application of nitrogen and pyridoxine. The data for NPK in leaves at the two growth stages are presented in Table 48 and are also summarised below.

4.7.4.1 Nitrogen

With regard to nitrogen application, $B_{N2.5}+F_{N1.25}$ gave the maximum leaf nitrogen content at both growth stages, except that at 50d, it was at par with that for $B_{N2.5}+F_{N2.5}$. Control, viz., $B_{N2.5}+F_W$ gave the lowest value and differed significantly from those for other nitrogen treatments at each stage. Regarding soaking treatment, S_2 had significantly higher leaf nitrogen content than S_1 at both growth stages.

Among interaction effects, it was noted that $(B_{N2.5}+F_{N1.25}) \times S_2$ produced maximum nitrogen content at both growth stages and the value given by this combination was

Table 48. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of summer moong var.K-851 (Mean of three replicates)

Basal+foliar treatments (kg N/ha)	Sampling stages (days after sowing)																	
	40			50			40			50			40			50		
	Soaking treatments (% pyridoxine)																	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Nitrogen (%)						Phosphorus (%)						Potassium (%)					
$B_{N2.5} + F_W$	2.24	2.36	2.30	1.33	1.42	1.38	0.147	0.156	0.152	0.123	0.124	0.124	1.64	1.65	1.65	1.20	1.24	1.22
$B_{N5} + F_W$	2.43	2.50	2.47	1.67	1.12	1.90	0.160	0.180	0.170	0.140	0.140	0.140	1.66	1.87	1.77	1.26	1.33	1.30
$B_{N2.5} + F_{N1.25}$	2.80	2.84	2.82	2.23	2.41	2.32	0.238	0.243	0.241	0.200	0.214	0.207	2.30	2.32	2.31	1.40	1.47	1.44
$B_{N2.5} + F_{N2.5}$	2.64	2.80	2.70	2.32	2.23	2.28	0.240	0.234	0.237	0.211	0.186	0.199	2.21	2.30	2.26	1.42	1.40	1.41
$B_{N2.5} + F_{N5}$	2.57	2.54	2.56	2.16	2.14	2.15	0.230	0.223	0.227	0.142	0.166	0.154	1.96	2.10	2.03	1.33	1.36	1.35
Mean	2.54	2.61		1.94	2.06		0.203	0.207		0.163	0.166		1.95	2.05		1.32	1.36	
C.D. at 5%	BF=0.045, S=0.029, BFxS=0.064			BF=0.108, S=0.068, BFxS=0.153			BF=0.005, S=0.003, BFxS=0.007			BF=0.004, S=0.002, BFxS=0.005			BF=0.071, S=0.045, BFxS=0.100			BF=0.035, S=0.022, BFxS=0.050		

equalled by $(B_{N2.5}+F_{N1.25}) \times S_1$ and $(B_{N2.5}+F_{N2.5}) \times S_2$ at 40d, while at 50d, it was equalled by $(B_{N2.5}+F_{N2.5}) \times S_2$ only (Table 48). The interaction $(B_{N2.5}+F_{N1.25}) \times S_2$ increased leaf nitrogen content by 26.79 and 81.20% at 40 and 50d over $(B_{N2.5}+F_W) \times S_1$.

4.7.4.2 Phosphorus

As is evident from Table 48, maximum leaf phosphorus content was recorded in the treatment $B_{N2.5}+F_{N1.25}$ and its value differed significantly from those for the rest of the treatments at each growth stage, except at 40d, when it was equalled by $B_{N2.5}+F_{N2.5}$. Control $(B_{N2.5}+F_W)$ gave the lowest phosphorus content of leaves at all growth stages. Among the two levels of pyridoxine, S_2 gave significantly more phosphorus content than S_1.

Among the various combinations, the interaction $(B_{N2.5}+F_{N1.25}) \times S_2$ resulted in maximum leaf phosphorus content at both growth stages but the value was equalled by $(B_{N2.5}+F_{N1.25}) \times S_1$ and $(B_{N2.5}+F_{N2.5}) \times S_1$ at 40d and by $(B_{N2.5}+F_{N2.5}) \times S_1$ at 50d. An increase of 65.31 and 73.98% in leaf phosphorus content was recorded in $(B_{N2.5}+F_{N1.25}) \times S_2$ at 40 and 50d over $(B_{N2.5}+F_W) \times S_1$.

4.7.4.3 Potassium

Regarding the effect of nitrogen treatment, it was found that $B_{N2.5}+F_{N1.25}$ and $B_{N2.5}+F_{N2.5}$ (showing equal effect) had significantly maximum potassium content in leaves at both stages. Control ($B_{N2.5}+F_W$) gave the lowest value at both growth stages. Soaking the seeds in S_2 had higher potassium content than that recorded in S_1.

Pertaining to the interaction effect of nitrogen application and pyridoxine, it emerged that ($B_{N2.5}+F_{N1.25}$) x S_2 gave maximum potassium content in leaves. The value given by this combination was statistically equal with those for ($B_{N2.5}+F_{N2.5}$) x S_2, and ($B_{N2.5}+F_{N1.25}$) x S_1 at 40d, while at 50d the value was equalled by ($B_{N2.5}+F_{N2.5}$) x S_1 only (Table 48). The interaction ($B_{N2.5}+F_{N1.25}$) x S_2 increased leaf potassium content by 41.46 and 22.50% at 40 and 50d over ($B_{N2.5}+F_W$) x S_1.

4.7.5 Yield characteristics

Five yield parameters (pod number/plant, pod length, seed number/pod, 1,000 seed weight and seed yield) were studied at harvest. The individual and combined effects of nitrogen application and pyridoxine soaking treatments on these yield parameters were found to be significant, except pod length and 1,000 seed weight (Tables 49-50). The data are summarised below:

4.7.5.1 Pod number per plant

With regard to the effect of nitrogen treatments, $B_{N2.5}+F_{N1.25}$ produced maximum pods and its value differed significantly from those for all other nitrogen treatments.

Control ($B_{N2.5}+F_W$) produced minimum number of pods. Soaking the seeds in S_2 resulted in higher pod number per plant in comparison to S_1 (Table 49).

Among various interactions, ($B_{N2.5}+F_{N1.25}$) x S_2 produced maximum pods per plant and the increase due to this interaction over ($B_{N2.5}+F_W$) x S_1 was 90.5%.

4.7.5.2 Pod length

It is evident from Table 49 that the effect of nitrogen treatment, pyridoxine soaking and their interaction was non-significant.

4.7.5.3 Seed number per pod

Maximum seed number was noted in $B_{N2.5}+F_{N1.25}$. The value given by this treatment showed significant difference from all other treatment, except $B_{N2.5}+F_{N2.5}$. On the other hand, the control ($B_{N2.5}+F_W$) gave the lowest number of seeds per pod. Out of the two soaking treatments, S_2 produced more seeds **per** pod than S_1.

As far as interaction effect was concerned, ($B_{N2.5}+F_{N1.25}$) x S_2 **gave** maximum value but showed equal effect with ($B_{N2.5}+F_{N2.5}$) x S_1 and $B_{N2.5}+F_{N1.25}$ x S_1 (Table 49). The application of ($B_{N2.5}+F_{N1.25}$) x S_2 gave an increase of 26.70% over ($B_{N2.5}+F_W$) x S_1.

Table 49. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of summer moong var.K-851
(Mean of three replicates)

Basal+Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Pod number/plant			Pod length (cm)			Seed number/pod		
$B_{N2.5} + F_W$	14.00	14.00	14.00	8.03	8.17	8.10	10.00	11.00	10.50
$B_{N5} + F_W$	15.33	16.00	15.67	8.27	8.40	8.34	11.00	11.33	11.17
$B_{N2.5} + F_{N1.25}$	20.00	26.67	23.34	8.63	8.80	8.72	12.33	12.67	12.50
$B_{N2.5} + F_{N2.5}$	20.67	17.33	19.00	8.63	8.60	8.62	12.67	12.00	12.34
$B_{N2.5} + F_{N5}$	17.33	16.67	17.00	8.50	8.50	8.50	11.67	11.67	11.67
Mean	17.47	18.13		8.41	8.49		11.53	11.73	
C.D. at 5%	BF=0.86, S=0.54, BFxS=1.21			BF=N.S., S=N.S., BFxS=N.S.			BF=0.29, S=0.18, BFxS=0.41		

N.S.= Non-significant

4.7.5.4 1,000 seed weight

As mentioned earlier, nitrogen application, pyridoxine soaking treatments and their interaction had non-significant effect on this parameter (Table 50).

4.7.5.5 Seed yield

It is evident from Table 50 that individual as well as interaction effect of nitrogen and pyridoxine was significant.

Among various nitrogen application, $B_{N2.5}+F_{N1.25}$ gave maximum seed yield and the effect differed critically from those for all other treatments. Lowest seed yield was recorded in control $(B_{N2.5}+F_W)$.

Regarding pre-sowing seed soaking, treatment with the S_2 level of pyridoxine resulted in higher seed yield than on treating them with S_1.

As far as interaction effect was concerned, $(B_{N2.5}+F_{N1.25})\times S_2$ registered highest seed yield and differed significantly in its effect from all other treatments, except $(B_{N2.5}+F_{N2.5})\times S_1$. An increase of 20.27% over $(B_{N2.5}+F_W)\times S_1$ was noted due to interaction effect of $(B_{N2.5}+F_{N1.25})\times S_2$.

4.7.6 Seed protein content

A perusal of Table 50 revealed maximum seed protein content in plants receiving $B_{N2.5}+F_{N1.25}$. The value differed

Table 50. Effect of basal and foliar application of nitrogen (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of summer moong var. K-851
(Mean of three replicates)

Basal+Foliar treatments (kg N/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	1,000 seed weight (g)			Seed yield (q/ha)			Protein content (%)		
$B_{N2.5} + F_W$	42.44	42.44	42.44	10.26	10.33	10.30	21.22	21.26	21.24
$B_{N5} + F_W$	42.45	42.47	42.46	10.33	10.34	10.34	21.34	21.54	21.44
$B_{N2.5} + F_{N1.25}$	42.57	42.86	42.72	11.83	12.34	12.09	22.42	22.73	22.58
$B_{N2.5} + F_{N2.5}$	42.86	42.67	42.77	12.20	11.42	11.81	22.56	22.33	22.45
$B_{N2.5} + F_{N5}$	42.67	42.48	42.58	10.64	11.33	10.99	21.65	21.83	21.74
Mean	42.60	42.58		11.05	11.15		21.84	21.94	
C.D. at 5%	BF=N.S., S=N.S., BFxS=N.S.			BF=0.13, S=0.08, BFxS=0.18			BF=0.12, S=0.08, BFxS=0.17		

N.S.=Non-significant

critically from those for all other treatments. The lowest protein content was found in the control ($B_{N2.5}+F_W$). Regarding the effect of soaking treatments, S_2 gave higher seed protein content compared to S_1.

Among the various interactions, ($B_{N2.5}+F_{N1.25}$) x S_2, equalled by ($B_{N2.5}+F_{N2.5}$) x S_1, produced significantly maximum protein content of seeds. An increase of 7.12% was noted in ($B_{N2.5}+F_{N1.25}$) x S_2 over ($B_{N2.5}+F_W$) x S_1.

These considered in their entirety reveal that, individually, the application of $B_{N2.5}+F_{N1.25}$ and pre-sowing seed treatment with 0.3 per cent pyridoxine (S_2) and collectively, ($B_{N2.5}+F_{N1.25}$) x S_2 proved optimum.

It may, therefore, be concluded that the application of 2.5 kg N/ha at the time of sowing, followed by 1.25 kg N/ha applied as foliar spray at 35d (together with 15 kg P and 35 kg K/ha) to summer moong seeds soaked before sowing in a 0.3% aqueous pyridoxine solution would boost the seed yield and quality of this important grain legume. The farmers should therefore, have no hesitation in adopting this inexpensive technique.

4.8 Experiment 8

This experiment on summer moong var.K-851 was also laid out according to factorial randomised block design. The effect of basal and foliar phosphorus application, pyridoxine soaking and their interactions on the growth and yield performance of the crop was studied (Table 51-56). The scheme of treatments is given in Table 9.

4.8.1 Growth characteristics

Five growth parameters, namely, root length, root nodule number, root fresh weight, root dry weight and leaf number were studied at 40 and 50d after sowing to investigate the individual and combined effect of various doses of phosphorus and two pyridoxine soaking treatments (Table 51-53).

The effect of various phosphorus treatments, pyridoxine soaking and their interactions on these parameters was found to be significant at both growth stages (40 and 50d).

4.8.1.1 Root length

The effect of phosphorus application, pyridoxine soaking treatment and their interaction was significant at both growth stages (Table 51).

Regarding phosphorus application, $B_{P10}+F_{P2}$ gave longest roots at both growth stages and the value differed significantly from those for all other treatments, except $B_{P15}+F_{P1}$, at both growth stages. The control ($B_{P10}+F_W$) gave the lowest value at both stages. Regarding the pyridoxine soaking treatment, S_2 produced longest roots at both stages than S_1.

Table 51. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on root length and root nodule number per plant of summer moong var.K-851 (Mean of three replicates)

Basal + foliar treatments (kg P/ha)	Sampling stages (days after sowing)											
	40			50			40			50		
	Soaking treatments (% pyridoxine)											
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Root length (cm)						Root nodule number					
$B_{P10} + F_W$	8.33	9.66	9.00	7.66	8.33	8.00	11.33	6.33	8.83	5.33	2.66	4.00
$B_{P15} + F_W$	9.66	10.08	9.87	8.66	9.00	8.83	10.24	6.67	8.46	5.66	4.33	5.00
$B_{P10} + F_{P1}$	8.66	10.66	9.66	8.00	10.66	9.33	8.66	17.66	13.16	3.33	2.33	2.83
$B_{P15} + F_{P1}$	9.66	11.60	10.63	8.66	11.33	10.00	10.33	21.66	16.00	4.00	8.66	6.33
$B_{P10} + F_{P2}$	9.66	11.66	10.66	8.66	11.66	10.16	8.66	23.22	15.94	3.00	9.33	6.17
$B_{P15} + F_{P2}$	9.00	10.33	9.67	8.00	10.33	9.17	8.33	15.22	11.78	2.33	2.66	2.50
Mean	9.16	10.67		8.27	10.22		9.59	15.13		3.94	5.00	
C.D. at 5%	BF=0.57, S=0.33, BFxS=0.80			BF=0.51, S=0.29, BFxS=0.72			BF=0.96, S=0.56, BFxS=1.36			BF=0.40, S=0.23, BFxS=0.57		

Among various interactions, $(B_{P10}+F_{P2}) \times S_2$, equalled by $(B_{P15}+F_{P1}) \times S_2$, produced maximum root length at either growth stage. The effect of $(B_{P10}+F_{P2}) \times S_2$ manifested itself in an increase of 39.97 and 52.22% in root length at 40 and 50d over $(B_{P10}+F_W) \times S_1$.

4.8.1.2 Root nodule number per plant

With regard to phosphorus application, $B_{P10}+F_{P2}$ resulted in maximum number of root nodules and its value was at par with that for $B_{P15}+F_{P1}$ at either growth stage and differed critically from those for other phosphorus treatments. Lowest value was given by the treatment $B_{P15}+F_W$, which was equalled by $B_{P10}+F_W$ at 40d, while at 50d, $B_{P10}+F_{P1}$ and $B_{P15}+F_{P2}$, being statistically equal, showed poorest effect. Soaking seeds in S_2 produced more nodules compared with S_1.

Regarding the interaction effect, $(B_{P10}+F_{P2}) \times S_2$ produced maximum root nodules at both stages (Table 51). The increase in root nodule number over $(B_{P10}+F_W) \times S_1$ due to this interaction was 104.94 and 75.05% at 40 and 50d respectively.

4.8.1.3 Root fresh weight per plant

As is evident from Table 52, $B_{P10}+F_{P2}$ gave maximum value but was equalled by $B_{P15}+F_{P1}$ at both growth stages. The control $(B_{P10}+F_W)$ gave the lowest fresh weight of root at both stages. More fresh weight was recorded in S_2 than S_1.

Table 52. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on fresh and dry weights of root per plant of summer moong var. K-851 (Mean of three replicates)

Basal + foliar treatments (kg P/ha)	Sampling stages (days after sowing)											
	40			50			40			50		
	Soaking treatments (% pyridoxine)											
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Fresh weight of root (g)						Dry weight of root (g)					
$B_{P10} + F_W$	0.373	0.533	0.453	0.649	0.645	0.647	0.190	0.230	0.210	0.352	0.300	0.326
$B_{P15} + F_W$	0.633	0.644	0.639	0.546	0.963	0.755	0.270	0.280	0.275	0.306	0.423	0.365
$B_{P10} + F_{P1}$	0.480	0.705	0.593	0.597	1.030	0.814	0.198	0.306	0.252	0.296	0.446	0.371
$B_{P15} + F_{P1}$	0.623	0.724	0.674	0.958	1.190	1.070	0.276	0.333	0.305	0.393	0.496	0.445
$B_{P10} + F_{P2}$	0.596	0.743	0.670	0.606	1.270	0.938	0.233	0.360	0.297	0.264	0.553	0.409
$B_{P15} + F_{P2}$	0.483	0.686	0.585	0.794	0.980	0.887	0.200	0.303	0.252	0.294	0.423	0.359
Mean	0.531	0.673		0.692	1.010		0.228	0.302		0.318	0.440	
C.D. at 5%	BF=0.028, S=0.016, BFxS=0.039			BF=0.055, S=0.032, BFxS=0.078			BF=0.024, S=0.014, BFxS=0.034			BF=0.053, S=0.030, BFxS=0.075		

The interaction $(B_{P10}+F_{P2}) \times S_2$ proved best and produced the maximum fresh weight at both growth stages, except 40d, when its value was at par with those for $(B_{P10}+F_{P1}) \times S_2$ and $(B_{P15}+F_{P1}) \times S_2$. The interaction $(B_{P10}+F_{P2}) \times S_2$ gave an increase of 99.20 and 95.69% in root fresh weight at 40 and 50d respectively over $(B_{P10}+F_W) \times S_1$.

4.8.1.4 Root dry weight per plant

The effect of phosphorus application, pyridoxine soaking treatment and their interaction was found to be significant (Table 52).

Maximum root dry matter was produced at both growth stages by the plants receiving $B_{P15}+F_{P1}$ and the effect of this treatment was significantly different from those for all other treatments, except, $B_{P10}+F_{P2}$. The lowest value was given by the control $(B_{P10}+F_W)$ at both growth stages and the value differed significantly from those for the other treatments at 40d; but at 50d, it was equalled by some other phosphorus treatments. Regarding soaking treatment, S_2 produced significantly more dry matter of root in comparison to S_1 at both stages.

The interaction $(B_{P10}+F_{P2}) \times S_2$ gave maximum value at both stages; but it was at par with that for $(B_{P15}+F_{P1})$. An increase of 89.47 and 57.10% due to $(B_{P10}+F_{P2}) \times S_2$ was noted over $(B_{P10}+F_W) \times S_1$.

4.8.1.5 Leaf number per plant

Among the different phosphorus treatments, $B_{P15}+F_{P1}$ produced the maximum number of leaves at both stages, except at 50d; where the value was statistically equal to that for $B_{P10}+F_{P2}$. The lowest number of leaves was recorded in the control ($B_{P10}+F_{W}$) at both stages. With regard to the soaking treatment, S_2 produced more leaves at both growth stages compared to S_1 (Table 53).

Regarding the various interactions, $(B_{P10}+F_{P2}) \times S_2$, equalled by $(B_{P15}+F_{P1}) \times S_2$, produced maximum leaves at both growth stages. An increase of 40.00 and 66.67% was given by $(B_{P10}+F_{P2}) \times S_2$ at 40 and 50d respectively over $(B_{P10}+F_{W}) \times S_1$.

4.8.2 Net assimilation rate (NAR)

Net assimilation rate was calculated for 30-40 and 40-50d interval to investigate the individual and combined effects of various phosphorus and pyridoxine treatments. It was noted that the effect of these treatments alone and in combination, was significant at each interval (Table 53).

Regarding the phosphorus treatment, $B_{P10}+F_{P2}$ (equalled by $B_{P15}+F_{P1}$) gave maximum NAR at each interval. At 30-40d, $B_{P15}+F_{W}$ also showed equal effect with the above mentioned two phosphorus treatments. Soaking the seeds in S_2 level of pyridoxine gave more NAR at both intervals compared to S_1.

Table 53. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf number per plant, net assimilation rate (NAR) and nitrate reductase activity (NRA) of summer moong var.K-851

(Mean of three replicates)

Basal + foliar treatments (kg P/ha)	Sampling stages (days after sowing)																	
	40			50									40			50		
	Soaking treatments (% pyridoxine)																	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Leaf number						NAR ($\times 10^{-4}$ g/cm^2/d) (30-40d interval)			(40-50d interval)			NRA (n mol NO_2^- /g/h)					
B_{P10} + F_W	15.00	15.00	15.00	18.00	21.00	19.50	10.05	8.36	9.21	2.67	2.95	2.81	105.43	106.55	105.99	102.44	106.53	104.49
B_{P15} + F_W	18.00	18.00	18.00	24.00	24.00	24.00	11.64	10.35	11.00	3.44	3.63	3.54	115.25	114.45	114.85	110.24	114.45	112.35
B_{P10} + F_{P1}	15.00	18.00	16.50	18.00	27.00	22.50	7.87	10.85	9.36	2.90	3.75	3.33	108.36	118.35	113.36	104.54	115.35	109.95
B_{P15} + F_{P1}	18.00	21.00	19.50	24.00	30.00	27.00	10.08	13.09	11.59	3.53	4.03	3.78	118.72	120.10	119.41	112.70	117.10	114.90
B_{P10} + F_{P2}	15.00	21.00	18.00	24.00	30.00	27.00	9.43	15.27	12.35	3.35	4.10	3.73	114.54	124.24	119.39	109.08	120.33	114.71
B_{P10} + F_{P2}	15.00	18.00	16.50	18.00	24.00	21.00	7.87	7.59	7.73	2.90	3.74	3.32	106.08	114.74	110.41	106.09	114.53	110.31
Mean	16.00	18.50		21.00	26.00		9.49	10.92		3.13	3.70		111.40	116.41		107.52	114.72	
C.D. at 5%	BF=0.99, S= 0.55, BFxS=1.34			BF=2.04, S=1.18, BFxS=2.88			BF=1.46, S=0.85, BFxS=2.07			BF=0.233, S=0.135, BF=0.330			BF=2.75, S=1.59, BFxS=3.89			BF=1.80, S=1.04, BFxS=2.55		

Among the various interactions, $(B_{P10}+F_{P2}) \times S_2$ resulted in maximum NAR at both growth stages and the value significantly differed from those for the remaining interactions at both intervals, except at the 40-50d interval when it was at par with that for $(B_{P15}+F_{P1}) \times S_2$. The interaction $(B_{P10}+F_{P2}) \times S_2$ gave an increase in NAR of 51.94 and 53.56% over $(B_{P10}+F_W) \times S_1$ at 30-40 and 40-50d intervals respectively.

4.8.3 Nitrate reductase activity (NRA)

Nitrate reductase activity of leaves was estimated at 40 and 50d growth stages. The effect of various levels of phosphorus application and soaking treatments alone and in combination was found to be significant at each stage (Table 53).

The maximum enzyme activity was recorded in plants receiving $B_{P15}+F_{P1}$ and it differed critically from those for the other treatments, except $B_{P10}+F_{P2}$, which gave equal effect at each growth stage. The lowest enzyme activity was noted in the control $(B_{P10}+F_W)$ at both stages. Soaking the seeds in S_2 level of pyridoxine solution showed more enzyme activity than S_1 at both growth stages.

With regard to the effect of interaction, $(B_{P10}+F_{P2}) \times S_2$ had the maximum NRA at both stages. This interaction gave an increase of 17.84 and 17.46% over $(B_{P10}+F_W) \times S_1$ at 40 and 50d respectively.

4.8.4 Leaf NPK content

The effect of different phosphorus levels and pyridoxine soaking treatments and their interaction on leaf NPK content was significant at both growth stages (Table 54).

4.8.4.1 Nitrogen

With regard to phosphorus treatments, it was noted that $B_{P10}+F_{P2}$ (equalled $B_{P15}+F_{P1}$) resulted in maximum accumulation of leaf nitrogen at both growth stages and the value differed statistically from those for other phosphorus treatments. The lowest value was given by the control ($B_{P10}+F_{W}$) at both stages, except 40d, when the value was equalled by $B_{P15}+F_{P2}$. Soaking the seeds in S_2 proved optimum and the value differed critically from that for S_1 at both stages.

Among various interactions, application of ($B_{P10}+F_{P2}$) x S_2, showing equal effect with ($B_{P15}+F_{P1}$) x S_2, had maximum leaf nitrogen content at both growth stages (Table 54). The combined dose of ($B_{P10}+F_{P2}$) x S_2 increased leaf nitrogen by 23.36 and 29.32% over ($B_{P10}+F_{W}$) x S_1 at 40 and 50d respectively.

4.8.4.2 Phosphorus

Regarding phosphorus application, $B_{P15}+F_{P1}$ resulted in significantly maximum accumulation of phosphorus in leaves at both stages, except at 40d, when the value was equalled by $B_{P10}+F_{P2}$. The control $B_{P10}+F_{W}$ gave the lowest value at both stages. Regarding pre-sowing seed treatments, S_2 resulted

Table 54. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on leaf NPK content of summer moong var.K-851

(Mean of three replicates)

Basal+foliar treatments (kg P/ha)	Sampling stages (days after sowing)																	
	40			50			40			50			40			50		
	Soaking treatments (% pyridoxine)																	
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Nitrogen (%)						Phosphorus (%)						Potassium (%)					
$B_{P10} + F_W$	2.14	2.23	2.19	1.33	1.35	1.34	0.223	0.235	0.229	0.167	0.167	0.167	2.83	2.76	2.80	2.35	1.62	1.99
$B_{P15} + F_W$	2.32	2.34	2.33	1.43	1.52	1.48	0.238	0.246	0.242	0.173	0.193	0.183	2.86	3.35	3.11	1.74	1.86	1.80
$B_{P10} + F_{P1}$	2.08	2.43	2.26	1.29	1.64	1.47	0.208	0.248	0.228	0.144	0.208	0.176	2.62	3.46	3.04	1.42	2.58	2.00
$B_{P15} + F_{P1}$	2.32	2.59	2.46	1.44	1.70	1.57	0.246	0.263	0.255	0.188	0.213	0.201	2.96	3.52	3.24	1.83	2.68	2.26
$B_{P10} + F_{P2}$	2.32	2.64	2.48	1.42	1.72	1.57	0.237	0.266	0.252	0.134	0.215	0.175	2.57	3.74	3.16	1.63	2.80	2.22
$B_{P15} + F_{P2}$	2.03	2.35	2.19	1.18	1.60	1.39	0.203	0.253	0.228	0.146	0.202	0.174	2.68	3.42	3.05	1.56	1.36	1.46
Mean	2.20	2.43		1.35	1.59		0.226	0.252		0.159	0.200		2.75	3.38		1.76	2.15	
C.D. at 5%	BF=0.047, S=0.027, BFxS=0.066			BF=0.024, S=0.014, BFxS=0.034			BF=0.007, S=0.004, BFxS=0.011			BF=0.004, S=0.002, BFxS=0.005			BF=0.153, S=0.088, BFxS=0.216			BF=0.170, S=0.098, BFxS=0.240		

in more accumulation of phosphorus in leaves at both interval. The value differed critically from that for S_1.

Pertaining to various interactions, it was revealed that $(B_{P10}+F_{P2}) \times S_2$, equalled by $(B_{P15}+F_{P1}) \times S_2$, gave the maximum concentration of phosphorus in leaves at both growth stages (Table 54). The interaction $(B_{P10}+F_{P2}) \times S_2$ increased leaf phosphoros content by 19.28 and 28.74% over $(B_{P10}+F_W) \times S_1$ at 40 and 50d respectively.

4.8.4.3 Potassium

Maximum potassium content of leaves was recorded in plants receiving $B_{P15}+F_{P1}$ at each interval. The value was at par with those for $B_{P10}+F_{P2}$ and $B_{P15}+F_W$ at 40d and with that for $B_{P10}+F_{P2}$ at 50d. The lowest value was recorded in $B_{P10}+F_W$ at 40d and $B_{P15}+F_{P2}$ at 50d. Soaking the seeds in S_2 gave higher potassium content of leaves at both growth stages compared with S_1 (Table 54).

Among various interactions, $(B_{P10}+F_{P2}) \times S_2$ resulted in maximum accumulation of potassium in leaves at each interval. However, the value was statistically equal to that for $(B_{P15}+F_{P1}) \times S_2$ at both stages. Moreover, at 50d, $(B_{P10}+F_{P1}) \times S_2$ also showed equal effect with the above mentioned two interactions. An increase of 32.16 and 19.15% potassium content of leaves due to $(B_{P10}+F_{P2}) \times S_2$ over $(B_{P10}+F_W) \times S_1$ was noted at 40 and 50d respectively.

5.8.5 Yield characteristics

Five yield parameters (pod number/plant, pod length, seed number/pod, 1,000 seed weight and seed yield) were studied at harvest. The effect of phosphorus, pyridoxine soaking treatments and their interaction was significant on all yield parameters. The data are summarised in Tables 55-56 and are briefly described below.

4.8.5.1 Pod number per plant

Regarding phosphorus application, $B_{P10}+F_{P2}$ produced maximum number of pods and its effect differed critically from those for all other treatments, except, $B_{P15}+F_{P1}$. The poorest effect was given by the treatment $B_{P15}+F_{P2}$. Among the two levels of pyridoxine selected for soaking the seeds, S_2 produced more pods than S_1.

Among various interactions, $(B_{P10}+F_{P2}) \times S_2$ produced the maximum number of pods, the increase due to this treatment was 68.77% over $(B_{P10}+F_W) \times S_1$ (Table 55).

4.8.5.2 Pod length

Longest pods were obtained as a result of the application of $B_{P10}+F_{P2}$ and the average value differed significantly from those for all other treatments, except $B_{P15}+F_{P1}$. On the other hand, the control $(B_{P10}+F_W)$ showed poorest effect. With regard to soaking treatments, S_2 produced significantly longer pods than recorded in S_1.

Table 55. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters of summer moong var.K-851
(Mean of three replicates)

Basal+Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	Pod number/plant			Pod length (cm)			Seed number/pod		
$B_{P10} + F_W$	15.66	13.33	14.50	6.13	6.81	6.47	8.25	8.53	8.39
$B_{P15} + F_W$	14.33	15.33	14.83	7.05	7.13	7.09	9.38	9.45	9.42
$B_{P10} + F_{P1}$	12.09	17.04	14.57	6.23	7.86	7.05	7.75	10.88	9.32
$B_{P15} + F_{P1}$	15.05	22.34	18.70	7.06	7.88	7.47	9.25	11.09	10.17
$B_{P10} + F_{P2}$	13.33	26.43	19.88	7.06	7.97	7.52	9.12	11.14	10.13
$B_{P15} + F_{P2}$	13.67	11.34	12.51	6.25	7.56	6.91	7.25	9.53	8.39
Mean	14.02	17.64		6.63	7.54		8.50	10.10	
C.D. at 5%	BF=1.79, S=1.03, BFxS=2.53			BF=0.26, S=0.15, BFxS=0.37			BF=0.170, S=0.098, BFxS=0.240		

Regarding the effect of various interactions $(B_{P10}+F_{P2}) \times S_2$ registered maximum effect that differed critically from the effect of all other interactions, except $(B_{P10}+F_{P1}) \times S_2$ and $(B_{P15}+F_{P1}) \times S_2$. The interaction $(B_{P10}+F_{P2}) \times S_2$ increased pod length by 30.01% over $(B_{P10}+F_W) \times S_1$ (Table 55).

4.8.5.3 Seed number per pod

It is evident from the Table 55, $B_{P15}+F_{P1}$ produced maximum seeds per pod. However, the effect was at par with that of $B_{P10}+F_{P2}$; but these treatments differed significantly from all other treatments with respect to their effect on seed number per pod. The control $(B_{P10}+F_W)$, together with $B_{P15}+F_{P2}$, showing equal effect, gave the lowest value. Of the two pyridoxine levels, S_2 proved significantly better in comparison to S_1.

As far as interaction effect was concerned, $(B_{P10}+F_{P2}) \times S_2$ and $(B_{P15}+F_{P1}) \times S_2$, being statistically equal, produced the maximum seed number per pod. This interaction $(B_{P10}+F_{P2}) \times S_2$ showed 35.03% increase over $(B_{P10}+F_W) \times S_1$.

4.8.5.4 1,000 seed weight

Among various levels of phosphorus application, $B_{P15}+F_{P1}$ produced the heaviest seeds. However, the value given by this treatment was at par with the 1,000 seed weight noted in $B_{P10}+F_{P2}$ and $B_{P15}+F_W$. The lightest seed were noted in the control ($B_{P10}+F_W$). Regarding soaking treatment, S_2 produced heavier seeds as compared with S_1 (Table 56).

Regarding the various interactions, ($B_{P10}+F_{P2}$) x S_2 produced the heaviest seeds. The value given by this interaction was statistically equal with that for ($B_{P15}+F_{P1}$) x S_2. The interaction ($B_{P10}+F_{P2}$) x S_2 gave an increase of 3.36% in 1,000 seed weight over ($B_{P10}+F_W$) x S_1.

4.8.5.5 Seed yield

The effect of phosphorus application, pyridoxine soaking treatment and their interactions on seed yield was significant (Table 56).

Regarding basal plus foliar application of phosphorus, $B_{P15}+F_{P1}$ produced maximum and the value differed critically from those for the remaining treatments. The lowest seed yield was recorded in treatment $B_{P15}+F_W$. Pertaining to soaking treatments, S_2 level of pyridoxine gave higher seed yield than S_1.

Regarding the interaction effect, ($B_{P10}+F_{P2}$) x S_2 gave maximum seed yield and its effect differed significantly from those for the remaining interactions. An increase of 35.66% was noted due to ($B_{P10}+F_{P2}$) x S_2 over ($B_{P10}+F_W$) x S_1.

4.8.6 Seed protein content

It is evident from the Table 56 that maximum seed protein content was recorded in plants receiving $B_{P10}+F_{P2}$ and the

Table 56. Effect of basal and foliar application of phosphorus (BF) and pre-sowing seed treatment with pyridoxine (S) on yield parameters and seed protein content of summer moong var.K-851 (Mean of three replicates)

Basal+Foliar treatments (kg P/ha)	Soaking treatments (% pyridoxine)								
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
	1,000 seed weight (g)			Seed yield (q/ha)			Protein content (%)		
$B_{P10} + F_W$	39.54	39.89	39.72	9.76	9.44	9.60	20.54	19.98	20.26
$B_{P15} + F_W$	40.28	40.22	40.25	10.34	7.52	8.93	20.33	20.66	20.50
$B_{P10} + F_{P1}$	39.56	40.45	40.01	7.80	11.20	9.50	19.55	22.52	21.04
$B_{P15} + F_{P1}$	40.22	40.65	40.44	10.50	12.50	11.50	19.93	24.06	22.00
$B_{P10} + F_{P2}$	39.89	40.87	40.38	7.33	13.24	10.29	20.30	24.51	22.41
$B_{P15} + F_{P2}$	39.87	40.43	40.15	8.28	10.85	9.57	19.43	21.25	20.34
Mean	39.89	40.42		9.00	10.79		20.01	22.16	
C.D. at 5%	BF=0.19, S=0.11, BFxS=0.26			BF=0.33, S=0.19, BFxS=0.47			BF=0.25, S=0.14, BFxS=0.35		

minimum in plants to which $B_{P10}+F_W$ had been applied. However, the value was equal to those given by $B_{P15}+F_W$ and $B_{P15}+F_{P2}$. Soaking the seeds in S_2 resulted in significantly higher protein content in comparison to S_1.

When the interaction effect was taken into consideration, $(B_{P10}+F_{P2}) \times S_2$ gave the maximum protein content and showed 19.33% increase over $(B_{P10}+F_W) \times S_1$.

A perusal of the entire data of this experiment would reveal that:

(i) the application of $B_{P15}+F_{P1}$ among the individual phosphorous treatments,

(ii) pre-sowing seed treatment with 0.3 per cent aqueous pyridoxine solution, and

(iii) the combination of $(B_{P10}+F_{P2})$ and S_2 (in the presence of 5 kg N and 35 kg K/ha) proved optimum and economically feasible.

CHAPTER 5

DISCUSSION

CONTENTS

DISCUSSION

5.1 Introduction

The world-wide increase in environmental pollution and rapidly depleting energy resources have shaken many old and well-established practices with agriculture being no exception. This has consequently generated a global awakening and has discouraged indiscriminate use of synthetic fertilisers in order to conserve the environment and energy. In developing countries, like India, where a wide gap between production and consumption of fertilisers exists and the poor economic conditions of the farmers are ubiquitously prevalent (Subba Rao, 1979), the aforesaid awakening has much relevance. Thus, there are rigorous efforts to explore ways which could circumvent the situation without depleting the productivity of crops.

It is well known since time immemorial that leguminous crops not only act as the chief source of edible proteins but also leave residual nitrogen in the field which provides nourishment to the subsequent crop. The latter property is the outcome of a congenial symbiotic association between legume roots and diazotrophic rhizobia. As the root also acts as a conduit to supply nutrients and water to plants from the soil, it would be of considerable practical consequence if a well proliferated leguminous root system could be achieved by some physiological manipulation. Such a well developed root system would also provide more surface area for symbiotic association with rhizobium.

At Aligarh, Afridi, Samiullah and their associates, working on these assumptions tried, during the last decade or so, various growth promoting substances and succeeded in obtaining luxuriant root system of various crops, including grain legumes (Samiullah et al., 1988). They noted that among these substances, pre-sowing seed enrichment with pyridoxine (vitamin B_6) enhanced not only root growth and root nodule number but also yield and quality of lentil and moong (Afridi et al., 1985; Samiullah et al., 1985; Ansari, 1986; Ansari and Khan, 1986). The findings reported in the present thesis are further elaboration of the previous work on these two legumes. The main objective of the investigation was to explore if economy of applied nitrogenous and phosphatic fertilisers could be achieved by the use of new techniques that would encourage symbiotic biological dinitrogen fixation on the one hand and on the other to guard against the wastage of costly and scarce nitrogenous and phosphatic fertilisers, a large part of which becomes unavailable to plants soon after basal application due to fixation, leaching, volatilisation, etc. (Russell, 1950; Anonymous, 1971). For this purpose, eight field trails, four each on lentil (*Lens culinaris* L. Medic.) var. T-36 and moong (*Vigna radiata* L. Wilczek) var. K-851, were conducted with a view to study the effect of pre-sowing seed enrichment with minute quantities of pyridoxine on efficacious utilisation of soil and/or leaf-applied nitrogen or phosphorus by these crops.

5.2 Growth characteristics

Growth of plant organs results from orderly cell division, expansion and differentiation. These processes are dependent, among other factors, on proper supply of mineral nutrients and growth substances as well as on the genetic make up of the plants (Moorby and Besford, 1983). A suitable combination of these factors brings about healthy growth and development of plants which, in its turn, ensures good crop yield and quality.

In Experiment 1 on lentil, application of 30kg N/ha (B_{N30}) enhanced root length, root fresh and dry weight and leaf number at 60, 90 and 120d and root nodule number at 60 and 90d (Tables 11-13). In Experiment 5 on summer moong, application of 5 kg N/ha (B_{N5}) proved optimum for the aforesaid parameters, except root fresh weight, at 20, 30, 40 and 50d (Tables 33-35). However, basal application of 45 kg N/ha viz.,(B_{N45}) proved at par with B_{N30} in Experiment 1 and 10 kg N/ha (B_{N10}) to B_{N5} in Experiment 5, which would be considered " luxury consumption" in terms of Bouma (1983). The higher requirement of nitrogen for lentil than for summer moong could be explained on the basis of former being a long duration crop (140d) than the latter that takes only 60d to mature. These data confirm earlier studies conducted at Aligarh (Akhtar, 1985). In Experiments 3 and 7 nitrogen was applied in two splits, half of the optimum nitrogen dose (established in Experiment 1 for lentil and in Experiment 5 for summer moong) was given at the time of sowing and one sixth or one third nitrogen in Experiment 3; and one fourth or half of nitrogen in Experiment 7 at pod filling stage as supplemental foliar spray. Basal application of 15 kg N/ha with 5 kg leaf-applied N/ha ($B_{N15}+F_{N5}$) in Experiment 3 and 2.5 kg basal N/ha with 1.25 kg leaf-applied N/ha ($B_{N2.5}+F_{N1.25}$) in Experiment 7 promoted root length root nodule number, root fresh weight, root dry weight and leaf number in lentil at 120d and in summer moong at 40 and 50d (Tables 23-24 & 45-47). It clearly indicates that foliar spray of nitrogen was more efficient in lentil than in summer moong. The reason could be that lentil is a long duration crop and much of the basally applied nitrogen is subsequently lost, and the crop suffers a hidden hunger at later stages as has been pointed out above (Section 5.2, p. 205). In such a situation, supplemental application of nitrogen as foliar spray becomes beneficial in long duration crops.

In Experiment 2 on lentil, basal application of 30kg P/ha (B_{P30}) proved optimum for root length, root nodule number, root fresh weight, root dry weight and leaf number at all stages (Tables 17-19). In Experiment 6 on summer moong, however, no definite trend of the crop's response to phosphorus application could be registered. However, 15 kg P/ha and 30 kg P/ha gave equal effect for one or the other growth parameter at different growth stages (Tables 39-41). On the other hand, application of 20 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P20}+F_{P2}$) resulted in maximum values for root length, root nodule number, root fresh weight, root dry weight and leaf number in lentil at 120d in Experiment 4. But application of 30 kg basal P/ha and foliar spray of 1 kg P/ha ($B_{P30}+F_{P1}$) also gave an effect equal to that of $B_{P20}+F_{P2}$ for most of the parameters (Tables 28-29). In Experiment 8 on summer moong, application of 10 kg basal P/ha and foliar spray of 2 kg P/ha ($B_{P10}+F_{P2}$) and of 15 kg basal P/ha and foliar spray of 1 kg P/ha ($B_{P15}+F_{P1}$) proved equally effective for the aforesaid growth parameters at 40 and 50d stages (Tables51-53). The same reason is valid for beneficial effects of phosphorus spray as for those of nitrogen spray given above.

It may be emphasised that stimulation of root growth in field grown leguminous crops by either nitrogen or phosphorus application has not been reported so far in the literature. However, Drew *et al*. (1973), Drew and Saker (1975) and Drew (1975) noted enhanced growth of the seminal root system of barley grown under controlled conditions by localised supply of nitrogen and phosphorus.

In Experiment 1-8 on lengtil and summer moong (Tables 11-13, 17-19, 23-24, 28-29, 33-35, 39-41, 45-47, & 51-53), pre-sowing seed treatment with 0.3% pyridoxine (S_2) proved optimum for almost all growth parameters at all samplings. It indicates that lentil and summer moong showed similar response to pyridoxine treatment. A simple explanation may be that seeds of these crops contained approximately the same native pyridoxine content, the values being 22.42μg and 21.76μg/g dry weight of seed respectively, which were seemingly inadequate to sustain normal growth and development of either crop. Therefore, pyridoxine content in seeds may be taken as a criterion to decide whether plants will respond to the application of the vitamin or not. Application of exogenous pyridoxine as pre-sowing seed treatment seems to enhance the level of the endogenous seed pyridoxine to an extent that gave an initial boost to the emerging seedlings. These naturally continued to perform better at the later growth stages in both crops, a case of the so called " carry over effect" . These findings are in agreement with the views expressed by Samiullah et al. (1988). Stimulation of root parameters in the lentil and summer moong in Experiments 1-8 is not unexpected as pyridoxine has long been established to be the indispensable factor for the growth of excised roots of various plants (Bonner and Bonner, 1948). In fact, studies in vivo pertaining to root growth of legumes in relation to exogenous supply of pyridoxine are meagre; but Khan and Ansari (1984) reported increase in lateral root number in 10d old seedlings of Phaseolus radiatus (Urd) as a result of pre-sowing seed treatment with pyridoxine. Ansari (1986) also observed that pre-sowing seed enrichment with pyridoxine results in enhanced number of root nodule and root length in field grown lentil and summer moong.

As far as interaction of fertiliser treatments x pre-sowing seed enrichment with pyridoxine is concerned, B_{N30} x S_2 (Experiment 1), B_{P30} x S_1 (Experiment 2), (B_{N15}+F_{N5}) x S_2 (Experiment 3) and (B_{P20}+F_{P2}) x S_2 (Experiment 4) in lentil as well as B_{N5} x S_1 (Experiment 5), B_{P15} x S_2 (Experiment 6), ($B_{N2.5}$+$F_{N1.25}$) x S_2 (Experiment 7) and (B_{P10}+F_{P2}) x S_2 (Experiment 8) in summer moong proved optimum for most of the root parameters and leaf number at various stages (Tables 11-13, 17-19, 23-24, 28-29, 33-35, 39-41, 45-47 & 51-53).

These results confirm individual effects of fertiliser treatments and of seed enrichment with pyridoxine which seem to have acted synergistically upon the growth of root in general and leaf number in particular. Probably, soaking in pyridoxine solution facilitated root growth, providing more surface area for rapid absorption of nutrients (and water) from the soil and also for the establishment of symbiotic association between rhizobium and host plants. This assumption was corroborated by the field trials in which fertiliser treatments were given as split dose in two instalments. For example, enhanced root growth and leaf number were observed in Experiments 3, 4, 7 and 8 wherein half of the optimum doses of nitrogen and phosphorus established in Experiments 1, 2, 5 and 6 respectively. This view also draws support from the observation of equal leaf NPK accumulation in plants grown from treated seeds irrespective of their having received high or low doses of nitrogenous and phosphatic fertiliser which will be discussed in Section 5.5.

5.3 Net assimilation rate (NAR)

As nine-tenth of the dry weight of the plant arises directly from photosynthesis, it was considered desirable to study the effect of the applied nutrients and vitamin and of their interaction on growth rates in terms of the size of the photosynthesising surface (taken as the mean area of leaves) and intensity of efficiency at which each unit of leaf functions (Milthorpe and Moorby, 1979). This efficiency is usually determined by computing NAR values which reflect a direct relationship with the yield of a crop. Therefore, NAR was calculated for different intervals in lentil and summer moong in all experiments.

Application of 30 kg basal N/ha (B_{N30}) in Experiment 1 and 5 kg basal N/ha (B_{N5}) in Experiment 5 promoted NAR in lentil at 60-90 and 90-120d intervals and in summer moong at 20-30, 30-40 and 40-50d intervals respectively (Tables 13 & 35). Moreover, supply of 15 kg basal N/ha with foliar spray of 5 kg N/ha ($B_{N15}+F_{N5}$) in Experiment 3 and of 2.5 kg basal N/ha with foliar spray of 1.25 kg N/ha ($B_{N2.5}+F_{N1.25}$) in Experiment 7 enhanced NAR in lentil at 90-120d interval and in summer moong at 30-40 and 40-50d intervals (Tables 24 & 47). In trials on phosphorus application, 30 kg basal P/ha (B_{P30}) in Experiment 2 and 15 kg basal P/ha (B_{P15}) in Experiment 6 proved optimum for NAR in lentil at 60-90 and 90-120d intervals and in summer moong at 20-30, 30-40 and 40-50d intervals (Tables 19 & 41). Also, application of 20 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P20}+F_{P2}$) in Experiment 4 and of 10 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P10}+F_{P2}$) in Experiment 8 resulted in maximum NAR in lentil at 90-120d interval and in summer moong at 30-40 and 40-50d intervals (Tables 29 & 53). It may be recalled that almost all the root growth parameters and leaf number were recorded to be maximum in the same treatments (Tables 11-13, 17-19, 23-24, 28-29, 33-35, 39-41, 45-47 & 51-53).

Thus, applied nitrogenous and phosphatic fertilisers promoted solar energy harvesting efficiency in both crops, resulting in elevated NAR values. This seems to be the first investigation in which NAR response of lentil and summer moong to nitrogen and phosphorus application was observed as no report on this aspect is available in the literature.

Soaking in 0.3% pyridoxine solution (S_2) resulted in maximum NAR values for both crops at various samplings in almost all experiments (Tables 13, 19, 24, 29, 35, 41, 47 & 53). These findings confirmed the earlier work of Ansari (1986) and Ansari and Khan (1986) who reported enhancement in NAR values at different time intervals in these two crops as a result of seed enrichment with pyridoxine.

Considering interaction between fertiliser treatments and soaking with pyridoxine, $B_{N30} \times S_2$ (Experiment 1), $B_{P30} \times S_1$ (Experiment 2), ($B_{N15}+F_{N5}$) $\times S_2$ (Experiment 3), ($B_{P20}+F_{P2}$) $\times S_2$ (Experiment 4), $B_{N5} \times S_2$ (Experiment 5), $B_{P15} \times S_2$ (Experiment 6), ($B_{N2.5}+F_{N1.25}$) $\times S_2$ (Experiment 7) and ($B_{P10}+F_{P2}$) $\times S_2$ (Experiment 8) promoted NAR values in the two crops at all time intervals, except NAR at 20-30d interval in Experiment 5 (Tables 13, 19, 24, 29, 35, 41, 47 & 53). As mentioned in Section 5.2 (p.209) and will be discussed below in Section 5.5 (p.216), soaking of seeds in pyridoxine solution helped to enhance the uptake of nutrients (Tables 14, 20, 25, 30, 36, 42, 48 & 54) due to the development of an efficient root system (Tables 11, 12, 17, 18, 23, 28, 33, 34, 39, 40, 45, 46, 51 & 52). There is every likelihood that these absorbed nutrients first promoted photosynthesis as a result of increase in leaf number noted in the above mentioned interactions and later got assimilated to produce various macromolecule which reflected itself in increased dry matter production (Tables 13, 19, 24, 29, 35, 41, 47 & 53). A somewhat similar NAR response in mustard to interaction of nitrogen and phosphorus with soaking of seeds in pyridoxine solution has been recently reported from the author's laboratory (Khan,1988). However, such studies on lentil and summer moong (or any other grain legume) have not been undertakenso far.

5.4 Leaf nitrate reductase activity (NRA)

Plants absorb large quantities of inorganic nitrogen from the soil in the form of nitrate. Once inside the plants, the nitrate is reduced to ammonia before being incorporated, via amino acid formation, into the more complex organic molecules like proteins and nucleic acids and some secondary nitrogenous metabolites. The first step in the sequence of these reactions is regulated by nitrate reductase that reduces nitrate to nitrite (Nicholas and Nason, 1954; Salisbury and Ross, 1986). The leguminous crops also exhibit another mechanism, i.e., dinitrogen fixation through nitrogenase system. However, being more rapid and convenient as well as having relationship with grain yield and quality in lentil and summer moong (Akhtar et al., 1984; Ansari et al., 1985; Samiullah et al., 1985; Ansari, 1986), the assay of NRA was preferred over that of nitrogenase.

Application of 45 kg basal N/ha (B_{N45}) in Experiment 1 promoted leaf NRA level in lentil at 60, 90 and 120d that was equalled by 30 kg basal N/ha (B_{N30}) at 60 and 120d (Table 13). In Experiment 5 on summer moong, application of 5 kg basal N/ha (B_{N5}) and 10 kg basal N/ha (B_{N10}), being at par, resulted in optimum leaf NRA level at 20, 30, 40 and 50 (Table 35). Further, split application of 15 kg basal N/ha with foliar spray of 5 kg N/ha ($B_{N15}+F_{N5}$) in Experiment 3 and of 2.5 kg basal N/ha with foliar spray of 1.25 kg N/ha ($B_{N2.5}+F_{N1.25}$) in Experiment 7 proved optimum for leaf NRA level in lentil at 120d and summer moong at 40 and 50d (Tables 24 &47). True that the form in which nitrogen was applied was urea (and not nitrate), urea yields nitrate rapidly within a few days of its application to normal soil having pH > 7.0 (Table 1) due to nitrification by micro-organism (Bidwell, 1979; Ross and Salisbury, 1986). The nitrate thus formed on being absorbed by the roots, induces as well as stabilises the nitrate reductase system in the plants which is reflected in the higher activity of the enzyme in the leaf (Afridi and Hewitt, 1962, 1964).

Enhancement of NRA level by foliar spray of nitrogen as urea in Experiments 3 and 7 is rather difficult to interprete under the given set of circumstances. This aspect, however, needs to be further investigated as there is no report relating to enhancement of leaf NRA level due to leaf applied urea.

Application of 30 kg basal P/ha (B_{P30}) in Experiments 2 and 6 resulted in maximum leaf NRA levels in both crops at all stages (Tables 19 & 41). Moreover, split application of 20 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P20}+F_{P2}$) in Experiment 4 and 10 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P10}+F_{P2}$) in Experiment 8 invariably promoted leaf NRA level in lentil at 120d and summer moong at 40 and 50d (Tables 29 & 53). The role of phosphorus in elevating leaf NRA level is indirect and seems to be related to higher levels of inorganic phosphorus in leaf tissues (Tables 14, 20, 25, 30, 36, 42, 48 & 54) that is subsequently responsible for phosphorylation and diversion of simple sugars towards respiration as a result of the release of photosynthates from the chloroplats. Thus, oxidation of these sugars could have generated more reducing power for nitrate reductase mediated NO_3^- reduction (Marschner, 1986, p. 230).

Seed enrichment with 0.3% pyridoxine solution (S_2) invariably enhanced leaf NRA level in both crops at all stages of growth in all experiments, except Experiment 6 (Tables 13, 19, 24, 29, 35, 41, 47 & 53). In Experiment 6, the trend of leaf NRA level in response to pyridoxine application showed slight alteration as 0.2% (S_1) pyridoxine solution promoted leaf NRA level in summer moong at 20 and 30d and S_1 and S_2 (being at par), at 40 and 50d (Table 41). Similar NRA response of lentil and summer moong to pre-sowing seed treatment with pyridoxine has been highlighted by Samiullah *et al*. (1988). One plausible explanation seems to be that pyridoxine accelerated the uptake of nitrate by the roots of lentil and moong by providing larger surface area for absorption (Tables 11,17, 23, 28, 33, 39, 45 & 51). It might have resulted in higher activity of nitrate reductase which not only requires its substrate (nitrate) for induction but also for stabilisation as mentioned above (Hewitt and Afridi, 1959; Afridi and Hewitt, 1962, 1964). The alternative possibility may be that pyridoxine directly induced the synthesis of nitrate reductase. Such direct induction of NRA by other growth regulators, for example GA or GA + cytokinin in tobacco leaves and by cytokinin in embryos of *Agrostemma githago* and in cucumber cotyledons has been documented by Roth-Bejerano and Lips (1970), Kende *et al*. (1971), Hirschberg *et al*. (1972), Kende and Shen (1972) and Knypl (1973).

Considering interaction between fertiliser and soaking treatments, $B_{N30} \times S_2$ (Experiment 1), $B_{P30} \times S_1$ (Experiment 2), $(B_{N15}+F_{N5}) \times S_2$ (Experiment 3), $(B_{P20}+F_{P2}) \times S_2$ (Experiment 4), $B_{N5} \times S_1$ (Experiment 5), $B_{P15} \times S_2$ (Experiment 6), $(B_{N2.5}+F_{N1.25}) \times S_2$ (Experiment 7) and $(B_{P10}+F_{P2}) \times S_2$ (Experiment 8) resulted in the highest leaf NRA levels in both crops at most of stages. These results broadly display a strong synergism between pyridoxine and phosphorus treatments (Tables 13, 19, 24, 29, 35, 41, 47 & 53).

5.5 Leaf NPK content

Leaf analysis is considered a reliable index of the mineral status of the soil as well as an indication on the mineral requirements of the plant (Lundegårdh, 1943, 1947, 1951). Leaf nutrient content has been established to be related to vegetative as well as reproductive growth of crop plants (Lundegårdh, 1951; Inam et al., 1982; Akhtar, 1985; Ansari, 1986). Therefore, leaf NPK content was estimated at various growth stages in the present study in response to nitrogen, phosphorus and pyridoxine application alone and in combination.

The concentration of NPK in leaves was generally more in lentil (Tables 14, 20, 25-30) than in summer moong (Tables 36, 42, 48 & 54). This clearly establishes higher requirement of these nutrients by the former crop. By and large, nitrogen and phosphorus application enhanced the contents of leaf NPK in both crops at various stages, with the application of 30 kg basal N/ha (B_{N30}) in Experiment 1, 30 kg basal P/ha (B_{P30}) in Experiment 2, 5 kg basal N/ha (B_{N5}) in Experiment 5 and 30 kg basal P/ha (B_{P30}) in Experiment 6 proving optimum (Tables 14, 20, 36, 42). These findings corroborate the earlier results of several workers who obtained high content of leaf NPK in various crops as a result of individual application of nutrients (Lundegårdh, 1951; Shankar and Kushwaha, 1971; Sinha, 1971; Khare *et al*., 1973; Rajendran and Krishnamoorthy, 1975; Ravankar and Badhe, 1975; Parode *et al*., 1977; Sampet, 1978; Bassiri *et al*., 1979; Kumar *et al*., 1979; Sameni *et al*., 1979; Ali *et al*., 1981; Sivasankar *et al*., 1981; Paricha *et al*., 1983; Rao *et al*., 1983; Akhtar *et al*., 1984; Akhtar *et al*., 1987).

Split application of 15 kg basal N/ha with foliar spray of 5 kg N/ha ($B_{N15}+F_{N5}$) in Experiment 3 and of 20 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P20}+F_{P2}$) in Experiment 4 on lentil as well as of 2.5 kg basal N/ha with foliar spray of 1.25 kg N/ha ($B_{N2.5}+F_{N1.25}$) in Experiment 7 and 10 kg basal P/ha with foliar spray of 2 kg P/ha ($B_{P10}+F_{P2}$) in Experiment 8 on summer moong exhibited maximum leaf NPK content at all stages of growth (Tables 25, 30, 48 & 54). This effect was expected due to direct enrichment of leaves with nutrients. However, leaf applied nitrogen and phosphorus might have also increased indirectly the uptake of nutrients including NPK through the roots, ultimately resulting in an increased transfer of these nutrients to the shoot (Asen *et al*., 1953, 1954; Boynton, 1954; Thorne, 1957; Wittwer and Teubner, 1959; Wittwer and Bukovac, 1969). Thus, according to Dorokov (1957), Mastskov and Ikonenko (1958) and Ikonenko (1959), foliar application of nitrogen and phosphorus enhances the absorption of nutrients through roots by a series of reactions. First, an increase in photosynthesis results in the production of large quantities of organic substances in leaves. This is followed by their enhanced transport to the roots. As a result, there is an increase in root respiration, with consequent enhanced root growth providing a larger absorbing surface.

In Experiments 1-8 in general, pre-sowing seed treatment with 0.3% (S_2) pyridoxine solution exhibited maximum leaf NPK contents in both crops at various stages (Tables 14, 20, 25, 30, 36, 42, 48 & 54). Samiullah et al. (1988) have also mentioned in their review that pre-sowing seed treatment with pyridoxine enhanced leaf NPK contents in field grown lentil and summer moong. Accordingly, combinations including $B_{N30} \times S_2$ (Experiment 1), $B_{P30} \times S_1$ (Experiment 2), $(B_{N15}+F_{N5}) \times S_2$ (Experiment 3), $(B_{P20}+F_{P2}) \times S_2$ (Experiment 4), $B_{N5} \times S_1$ (Experiment 5), $B_{P15} \times S_2$ (Experiment 6), $(B_{N2.5}+F_{N1.25}) \times S_2$ (Experiment 7) and $(B_{P10}+F_{P2}) \times S_2$ (Experiment 8) proved optimum for leaf NPK contents at most sampling stages, suggesting a strong cummulative effect of fertiliser and soaking treatments (Tables 14, 20, 25, 30, 36, 42, 48 & 54). As has been mentioned in Section 5.2, it seems that the augmented endogenous levels of pyridoxine as a result of seed treatment enhanced the absorbing capacity of roots of lentil and summer moong via increased root growth resulting in higher "efficiency of soil-applied nutrient" in both crops.

5.6 Yield characteristics

Yield is the final manifestation of several complex morphological and physiological traits of a crop. According to Thorne (1966), vegetative growth before flowering has considerable (albeit indirect) influence on grain yield. This early growth affects the potential surfaces so that they are made available for photosynthetic activity after flowering by influencing the number and size of the photosynthesising sites (leaves). It is this surface that provides the products to the sinks (grains), thereby highlighting the dependence of reproductive growth on vegetative growth. However, these traits are, inturn, dependent upon various factors, including availability and proper balance of essential nutrients and their efficient absorption and utilisation.

Nitrogen and phosphorus treatments, B_{N45} (Experiment 1), B_{P30} (Experiment 2), $B_{N15}+F_{N5}$ (Experiment 3), $B_{P20}+F_{P2}$ (Experiment 4), B_{N5} (Experiment 5), B_{P30} (Experiment 6), $B_{N2.5}+F_{N1.25}$ (Experiment 7) and $B_{P15}+F_{P1}$ (Experiment 8) proved optimum for most yield attributes, including seed yield (Tables 15, 16, 21, 22, 26, 27, 31, 32, 37, 38, 43, 44, 49, 50, 55 & 56). It may be recalled that these treatments were also optimum for most of the growth parameters, NAR, leaf NRA and leaf NPK content in the respective experiments. These observations, therefore clearly established that seed yield depends upon integration of vegetative and reproductive growth as mentioned above. The present data are in agreement with the work of other scientists who reported positive effect of these nutrients (applied individually) on yield parameters (Choudhury, 1968; Sharma, 1970; Chowdhury et al., 1974;

Hamissa, 1974; Maheshwari, 1974; Panwar and Singh, 1975; Ravankar and Badhe, 1975; Kaul, 1976; Rama Krishnan et al., 1977; Nair and Aiyer, 1979; Bisen et al., 1980; Saxena and Wassimi, 1980; Vasimalai and Subramaniam, 1980; Panwar and Singh, 1981; Raghu et al., 1981; Saxena, 1981; Singh and Marok, 1981; Srivastava and Verma, 1981; Yaseen, 1981; Verma and Kalra, 1983).

Pertaining to the soaking treatments, 0.3% pyridoxine solution (S_2) proved optimum for most yield characteristics including seed yield, in all experiments. Such a beneficial effect of pyridoxine on the productivity of cereals and legumes has also been reported by other workers from the author's laboratory (Afridi et al., 1983; Samiullah et al., 1985). As mentioned earlier, these treatments also proved optimum for most of the growth characteristics of root, NAR, leaf NRA and leaf NPK contents. Thus, the cumulative effect of these parameters resulted in enhanced seed yield of both crops.

Considering the interactions, B_{N30} x S_2 (Experiment 1), B_{P30} x S_1 (Experiment 2), (B_{N15}+F_{N5}) x S_2 (Experiment 3), (B_{P20}+F_{P2}) x S_2 (Experiment 4), B_{N5} x S_1 (Experiment 5), B_{P15} x S_2 (Experiment 6), ($B_{N2.5}$+$F_{N1.25}$) x S_2 (Experiment 7) and (B_{P10}+F_{P2}) x S_2 (Experiment 8) proved optimum for most yield attributes in all experiments (Tables 15, 16, 21, 22, 26, 27, 31, 32, 37, 38, 43, 44, 49, 50, 55 & 56). Experiments 4 and 8 included foliar spray of phosphorus on lentil and summer moong respectively. It seems that spray of phosphorus with pyridoxine soaking treatment resulted synergistically in translocation of photosynthates to the developing grains and thereby, favoured efficient grain filling. It is well established that high level of phosphorus in the tissue favours phosphorylation of sugars and their subsequent translocation (Marschner, 1986). However, interaction of nitrogen or phosphorus with pyridoxine seems in general to have promoted either differentiation of flowers or retention of pods after maturation or both, and thus resulted in enhanced seed yield. Moreover, the same interactions of nitrogen or phosphorus with pyridoxine were also found to be optimum for most of the growth parameters in the case of root, NAR, leaf NRA and leaf NPK contents. Therefore, profitable cultivation of these crops may be obtained by pre-sowing seed treatment with 0.3% pyridoxine solution, basal application 15 kg N and 20 kg P/ha and foliar spray of 5 kg N and 2 kg P/ha to lentil. On the other hand, in the case of summer moong the same seed treatment would give excellent results by being applied with 5 kg N and 10 kg P/ha and foliar spray of 2 kg P/ha only. It would result in a net saving of 10 kg N and 8 kg P/ha in lentil and although the saving of nitrogen is negligible 18 kg P/ha could be saved in summer moong.

5.7 Seed protein content

Grain legumes are a rich source of vegetable proteins in Indian diet. As such, not only the yield but also the protein content of the grain should be taken into consideration and if it is low remedial measures would be necessary for augmenting it. The significant data pertaining to this aspect are discussed below.

In all the eight experiments, application of nitrogen and phosphorus promoted seed protein content in both crops, B_{N30} (Experiment 1), B_{P30} (Experiment 2),, $B_{N5}+F_{N1}$ (Experiment 3), $B_{P20}+F_{P2}$ (Experiment 4), B_{N5} (Experiment 5), B_{P30} (Experiment 6), $B_{N2.5}+F_{N1.25}$ (Experiment 7) and $B_{P10}+F_{P2}$ (Experiment 8) proving optimum (Tables 16, 22, 27, 32, 38, 44, 50 & 56). This would be expected as nitrogen is the chief constituent of proteins while phosphorus is involved in protein synthesis via supply of energy-rich ATP (Hewitt, 1963). The positive effect of individual nutrients, including nitrogen and phosphorus, has also been established by a few workers (Chowdhury, 1968; Arora and Luthra, 1972; Tiwari and Srivastava, 1974; Panwar and Singh, 1975; Kushwaha and Srivastava, 1978; Panwar and Singh, 1981).

In all experiments 0.3% pyridoxine solution (S_2) proved optimum for seed protein content in both crops (Tables 16, 22, 27, 32, 38, 44, 50 & 56). The beneficial effect of pyridoxine on seed protein content is not altogether surprising as this vitamin, being a co-enzyme of aminotransferases, helps in the synthesis of amino acids by utilising the organic acids produced during oxidation of carbohydrates in the Krebs cycle (Lehninger, 1984, p.258). The additional amino acids so produced are also incorporated into the proteins, shifting the metabolic balance in favour of protein formation and storage. The availability of phosphorus in addition to that of nitrogen, ensures the continuous utilisation of carbon skelatons for amino acid synthesis as well as that of energy-rich ATP for protein synthesis (Hewitt, 1963; Marschner, 1986, p. 230). This appears to be the most valid reason to explain why there exists a noteworthy synergism between supply of nitrogen or phosphorus and pyridoxine in promoting the seed protein content. Thus, it is understandableas to why $B_{N30} \times S_2$, $B_{P30} \times S_1$, $(B_{N15}+F_{N5}) \times S_2$, $(B_{P20}+F_{P2}) \times S_2$, $B_{N5} \times S_1$, $B_{P15} \times S_2$, $(B_{N2.5}+F_{N1.25}) \times S_2$, and $(B_{P10}+F_{P2}) \times S_2$ in Experiments 1-8 respectively enhanced seed protein content in the two crops.

5.8 Conclusion

A comparison of all experiments reveals that foliar spray of nitrogen was more efficacious and economical in lentil than in summer moong. The clear-cut effectiveness of leaf-applied phosphorus in both lentil and summer moong confirmed the increasingly low availability of this nutrient from the soil as the crops matured. Moreover, 0.3% pyridoxine solution applied as pre-sowing seed treatment invariably exhibited a pronounced stimulating effect on growth, development, yield and quality of both crops. Thus, pyridoxine seemed to promote " the efficiency of soil/leaf-applied nutrients" in lentil and summer moong. Therefore, profitable cultivation of lentil may be ensured on administering 0.3% pyridoxine solution to seeds with

CHAPTER 6

SUMMARY

SUMMARY

The importance of the problem " Growth and yield response of Lens culinaris L. Medic. (lentil) and Vigna radiata L. Wilczek (moong) to nitrogen phosphorus and pyridoxine application" has been briefly considered. In view of the lacunae in the understanding of the problem, justifications have been put forward for undertaking the present work (Chapter 1).

The history of inorganic plant nutrition and published papers on the physiological roles of nitrogen, phosphorus, potassium and pyridoxine and on their effect on the performance of lentil and moong have been reviewed, paying special attention to Indian work (Chapter 2).

Details of the materials and methods of all eight factorial randomised field experiments conducted and relevant meteorological and edaphic data have been given (Chapter 3).

The significant ($P \leqslant 0.05$) data (Chapter 4) have been discussed in the light of earlier findings (Chapter 5) and are summarised below;

Experiment 1 (1984-85) was conducted on lentil var. T-36 during " rabi " (winter) season to study the effect of basal nitrogen and pre-sowing seed enrichment with pyridoxine, added in the presence of 45 kg P and 30 kg K/ha uniformly, alone and in combination on (i) growth parameters (root length, root nodule number, fresh and dry weight of root and leaf number),

(ii) net assimilation rate (NAR), (iii) nitrate reductase activity (NRA), (iv) leaf NPK content , (v) yield parameters (pod number, pod length, seed number/pod, 1,000 seed weight and seed yield) and (vi) seed protein content. The doses of nitrogen were 15 (B_{N15}), 30 (B_{N30}), 45 (B_{N45}) and 60 (B_{N60}) kg N/ha and pre-sowing seed treatment, 0.0% (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3) aqueous pyridoxine solution. Growth parameters, NRA and leaf NPK content were studied at 60, 90 and 120d and NAR was computed for the periods 60-90d and 90-120d. Yield parameters and seed protein content were studied at harvest.

B_{N30} proved optimum for most of the parameters studied. The exceptions were dry weight of root at 120d, NAR at 90d, leaf potassium content at 120d, and pod number and seed yield, for which B_{N45} was found best. S_2 promoted almost all parameters studied. The interaction $B_{N30} \times S_2$ proved optimum with the exception of leaf number and leaf nitrogen contents at 120d, for which $B_{N30} \times S_2$ was found next to $B_{N45} \times S_2$. $B_{N30} \times S_2$ increased seed yield by 71.21% and seed protein content by 12.65% over $B_{N15} \times S_W$.

Experiment 2 (1984-85) was conducted on lentil var.T-36 during "rabi" season to study the effect of four basal doses of phosphorus, i.e., 15 (B_{P15}), 30 (B_{P30}), 45 (B_{P45}) and 60 (B_{P60}) kg P/ha, added in the presence of 45 kg N and 30 kg K/ha applied uniformly at the time of sowing, and pre-sowing seed treatment with four aqueous pyridoxine solution, i.e., 0.0% (S_W), 0.2% (S_1), 0.3% (S_2) and 0.4% (S_3), alone as well as in combination, on the same parameters as were selected in Experiment 1.

B_{P30} and S_2 proved optimum for most parameters. B_{P30} x S_1 proved optimum for most parameters, except fresh weight of root at 60d, NRA at 120d and leaf nitrogen content at 90d where the effect of this interaction was next to that of B_{P45} x S_2. B_{P30} x S_1 enhanced seed yield and seed protein content by 31.05% and 18.27% respectively compared with B_{P15} x S_W.

Experiment 3 (1985-86) was also conducted on lentil var.T-36 during "rabi" season to study the individual and combined effect of basal + foliar application of nitrogen ($B_{N15}+F_W$, $B_{N30}+F_W$, $B_{N15}+F_{N5}$, $B_{N30}+F_{N5}$, $B_{N15}+F_{N10}$ and $B_{N30}+F_{N10}$), in the presence of 30 kg P and 30 kg K/ha added uniformly at the time of soaking, and seed treatment with 0.2% (S_1) and 0.3% (S_2) pyridoxine solution on growth characteristics at 120d, NAR for 90-120d interval and yield parameters and seed protein content at harvest.

Individual and combined effect of $B_{N15}+F_{N5}$ and S_2 proved optimum for almost all parameters, $B_{N15}+F_{N5}$ x S_2 increased seed yield by 21.04% and seed protein content by 6.35% over ($B_{N15}+F_W$) x S_1. It resulted in a net saving of 10 kg N/ha compared with the optimum N requirement noted in Experiment 1.

Experiment 4 (1985-86) was also conducted on lentil var. T-36 during "rabi" season. The aim was to investigate the effect of basal + foliar application of phosphorus ($B_{P20}+F_W$, $B_{P30}+F_W$, $B_{P20}+F_{P1}$, $B_{P30}+F_{P1}$, $B_{P20}+F_{P2}$ and $B_{P30}+F_{P2}$), in the presence of 30 kg N and 30 kg K/ha added uniformly at the time of sowing, and soaking in 0.2% and 0.3% pyridoxine solution

(S_1 and S_2 respectively), alone and in all possible combinations, on the parameters selected in Experiment 1, 2 and 3 at 120d and at harvest.

Among different levels of phosphorus (basal+foliar) and soaking treatments, $B_{P20}+F_{P2}$ and S_2, alone as well as in combination, proved optimum for all parameters. Their combination resulted in an increase of 24.13% and 16.36% in seed yield and seed protein content respectively over $(B_{P20}+F_W) \times S_1$. This resulted in a net saving of 8 kg P/ha compared with the optimum dose determined in Experiment 2.

Experiment 5 (1985) was performed on summer moong (Vigna radiata L. Wilczek) var.K-851 during "zaid" (summer) season to investigate the effect of four applied nitrogen levels, viz., no nitrogen (B_{N0}), 5 kg N/ha (B_{N5}), 10 kg N/ha (B_{N10}) and 15 kg N/ha (B_{N15}), in the presence of 30 kg P and 35 kg K/ha added uniformly at the time of sowing, and four pre-sowing seed treatments with aqueous pyridoxine solution, i.e., 0.0% (S_W), 0.2% (S_1), 0.3%(S_2) and 0.4% (S_3), alone and in all possible combinations, on (i) growth parameters (root length, root nodule number, fresh and dry weights of root and leaf number), (ii) net assimilation rate (NAR), (iii) nitrate reductase activity (NRA), (iv) leaf NPK content (v) yield parameters (pod number/plant, pod length, seed number/pod, 1,000 seed weight and seed yield) and (vi) seed protein content. The growth parameters, NRA and leaf NPK content were studied at 20, 30, 40 and 50d, NAR was computed for 20-30d, 30-40d, and 40-50d intervals and yield parameters and seed protein content were determined at harvest.

B_{N5} and S_2 proved optimum for almost all parameters. B_{N5} x S_1 proved optimum for most of the parameters, except NAR for 20-30d, NRA at 50d, leaf phosphorus content at 30d, pod number/plant and seed number/pod at harvest, for which B_{N5} x S_1 was next to B_{N5} x S_2. B_{N5} x S_1 resulted in an increase of 31.72% and 7.86% in seed yield and seed protein content respectively over B_{N0} x S_W.

Experiment 6 (1985) was conducted on summer moong var.K-851 during " zaid" season to study the effect of basally applied phosphorus (B_{P15}, B_{P30}, B_{P45} and B_{P60}), in the presence of 10 kg N and 35 kg K/ha added uniformly at the time of sowing, and pre-sowing seed treatment with aqueous pyridoxine solution (S_W, S_1, S_2 and S_3), alone and in combination, on the same parameters as were selected in Experiment 5.

B_{P30} and S_2 separately proved optimum for all parameters, while B_{P15} x S_2 emerged as the best combination of basally applied phosphorus and pyridoxine soaking. It enhanced the seed yield and seed protein content by 31.06% and 11.75% respectively over B_{P15} x S_W.

Experiment 7 (1986) was also conducted on summer moong var. K-851 during " zaid" season to study the effect of basal + foliar application of nitrogen ($B_{N2.5}+F_W$, $B_{N5}+F_W$, $B_{N2.5}+F_{N1.25}$, $B_{N2.5}+F_{N2.5}$ and $B_{N2.5}+F_{N5}$), taking the optimal and sub-optimal basal doses determined in Experiment 5, in the presence of 15 kg P and 35 kg K/ha added uniformly at the time of sowing, and two pre-sowing seed treatments, viz., 0.2% (S_1)

and 0.3% (S_2) aqueous pyridoxine solution, alone and in combination, on the same parameters as were selected in Experiment 5. Growth parameters, NRA and leaf NPK content, were studied at 40 and 50d, NAR was computed for 30-40d and 40-50d intervals and yield parameters and seed protein content were determined at harvest.

$B_{N2.5}+F_{N1.25}$ and S_2, alone as also in combination, proved optimum for all parameters studied. Although it resulted in a saving of only 1.25 kg N/ha, it increased seed yield by 20.27% and seed protein content by 7.12% over $(B_{N2.5}+F_W) \times S_1$.

Experiment 8 (1986) was also conducted on summer moong var. K-851 during "zaid" season to study, if economy of phosphorus could be achieved by taking basal + foliar phosphorus ($B_{P10}+F_W$, $B_{P15}+F_W$, $B_{P10}+F_{P1}$, $B_{P15}+F_{P1}$, $B_{P10}+F_{P2}$ and $B_{P15}+F_{P2}$), added in the presence of 5 kg N and 35 kg K/ha applied uniformly at the time of sowing, and pre-sowing seed treatment with two concentrations of aqueous pyridoxine solution, i.e., 0.2% and 0.3% (S_1 and S_2 respectively), alone and in all possible combinations, on the same parameters as were selected in Experiment 5 and 6. Growth parameters, NRA and leaf NPK content were studied at 40 and 50d. NAR was computed for 30-40 and 40-50d intervals only and yield parameters and seed protein content were determined at harvest.

$B_{P10}+F_{P2}$ (equalled by $B_{P15}+F_{P1}$) and S_2 proved best for most parameters separately. $(B_{P10}+F_{P2}) \times S_2$ excelled all other interactions and proved optimum for all parameters, increasing seed yield and seed protein content by 35.66% and 19.33%

respectively over $(B_{P10}+F_W) \times S_1$ with a saving of 18 kg P/ha as compared with the optimum determined in Experiment 6.

The information contained in this thesis is new addition to the literature on the growth, development and seed quality of grain legumes in particular and crop plants in general in the following respects.

1. The optimum requirements of nitrogenous and phosphatic fertilisers for lentil and summer moong (Experiment 1, 2, 5 and 6) for the agro-climate obtaining at Aligarh (Western Uttar Pradesh)were determined with precisions.

2. The concentration of pre-sowing seed treatment with aqueous pyridoxine (vitamin B_6) solution for optimum performance of the two crops was repeatedly confirmed in all trials undertaken (Experiments 1-8).

3. The optimum combinations of nitrogenous or phosphatic fertilisers with soaking treatments were determined for the first time (Experiments 1-8)

4. Comparison of all experiments revealed that supplemental foliar spray of nitrogen and phosphorus was effective and economical for both lentil and moong. Pre-sowing seed treatment with an aqueous solution of 0.3% pyridoxine resulted invariably in a pronounced stimulating effect on yield and quality of both crops.

Thus, pyridoxine treatment promotes " soil and leaf-applied nutrient use efficiency" in both crops. Therefore, minimum application of nutrients (nittogen and phosphorus) in combination with 0.3% aqueous solution of pyridoxine treatment of seeds in the presence of appropriate Rhizobium inoculum may be exploited economically to augment the yield and seed quality of lentil and summer moong.

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APPENDIX

PREPARATION OF REAGENTS

The reagents for various biochemical determinations were prepared according to the following methods.

1. Reagents for pyridoxine estimation

a. Chloroimide reagent

100 mg of crystalline 2,6-dichloroquinone chloromide was dissolved in 250ml of isopropanol. The solution was kept in a glass-stoppered bottle in refrigerator and discarded when pink colour developed.

b. Ammonia-ammonium chloride solution

160g of ammonium chloride was dissolved in 70ml of distilled water in which 160ml of concentrated ammonia water (approximately 27%) was added. The solution was diluted upto 1,000ml with distilled water.

c. Boric acid solution

5g of boric was dissolved in 100ml of distilled water.

d. Pyridoxine hydrochloride solution

100mg of pyridoxine hydrochloride was dissolved in 1000ml of distilled water which was kept in an amber coloured bottle in refrigerator.

e. Buffer solution (pH - 3)

73g of sodium phosphate dihydrate and 167g of citric acid were dissolved in distilled water and diluted upto 1000 ml.

2. Reagents for nitrate reductase activity

a. Phosphate buffer (pH - 7.5)

13.6g of potassium dihydrogen orthophosphate was dissolved in 1000ml of distilled water (a). 17.42g of dipotassium monohydrogen orthophosphate was dissolved in 1000ml of distilled water (b). 160ml of solution 'a' and 840ml of solution 'b' were mixed for the preparation of the buffer.

b. Potassium nitrate solution (0.2M)

2.02g of potassium nitrate was dissolved in 100ml aqueous solution.

c. Isopropanol (5%)

5ml of isopropanol was mixed with 95ml of distilled water.

d. Chloramphenicol solution (0.5mg/ml)

50mg of chloramphenicol was dissolved in 100ml of distille water.

e. Sulphanilamide (1%)

1g of sulphanilamide powder was dissolved in 100ml of 3N-hydrochloric acid.

f. NED HCl solution (0.02%)

20mg of NED HCl (N-1-(naphthyl)-ethylene diamine dihydrochloric acid) was dissolved in 100ml of distilled water.

3. Reagents for NPK determination

a. Nessler's reagent

3.5g of potassium iodide was dissolved in 100ml of distilled water in which 4% mercuric chloride solution was added with stirring until a slight red precipitate remained (about 325ml of the solution was required). Thereafter, 120ml of sodium hydroxide with 250ml of distilled water were mixed. The volume was made upto 1000ml with distilled water. The mixture was decanted and kept in amber coloured bottle.

b. Molybdic acid reagent (2.5%)

6.25g of ammonium molybdate was dissolved in 175ml distilled water to which 75ml of 10N-sulphuric acid was added.

c. Aminonaphthol sulphonic acid

0.5g of 1-amino-2naphthol-4-sulphonic acid was dissolved in 195ml of 15% sodium bisulphite solution to which 5ml of 20% sodium sulphite solution was added. The solution was kept in amber coloured bottle.

4. Reagents for protein estimation

a. Reagent A

0.5% copper sulphate solution and 1% sodium sulphate solution were mixed in equal volumes.

b. Reagent B (carbonate-copper sulphate solution)

50ml of 2% sodium carbonate solution was mixed with 1ml of reagent 'A'.

c. Folin's reagent

100g of sodium tungstate and 25g of sodium molybdate were dissolved in 700ml of distilled water to which 50ml of 85% phosphoric acid and 100ml of concentrated hydrochloric acid were added. The solution was reflected on a heating mantle for 10h. At the end, 150g of lithium sulphate, 50ml of distilled water and 3-4 drops of liquid bromine were added. The reflex condensor was removed and the solution was boiled for 15min to remove excess bromine, cooled and diluted upto 1000ml. The strength of this acidic solution was adjusted to 1N by titrating it with 1N-sodium hydroxide solution.